

# ASTRONOMY

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**Exploring the Extreme Ultraviolet**

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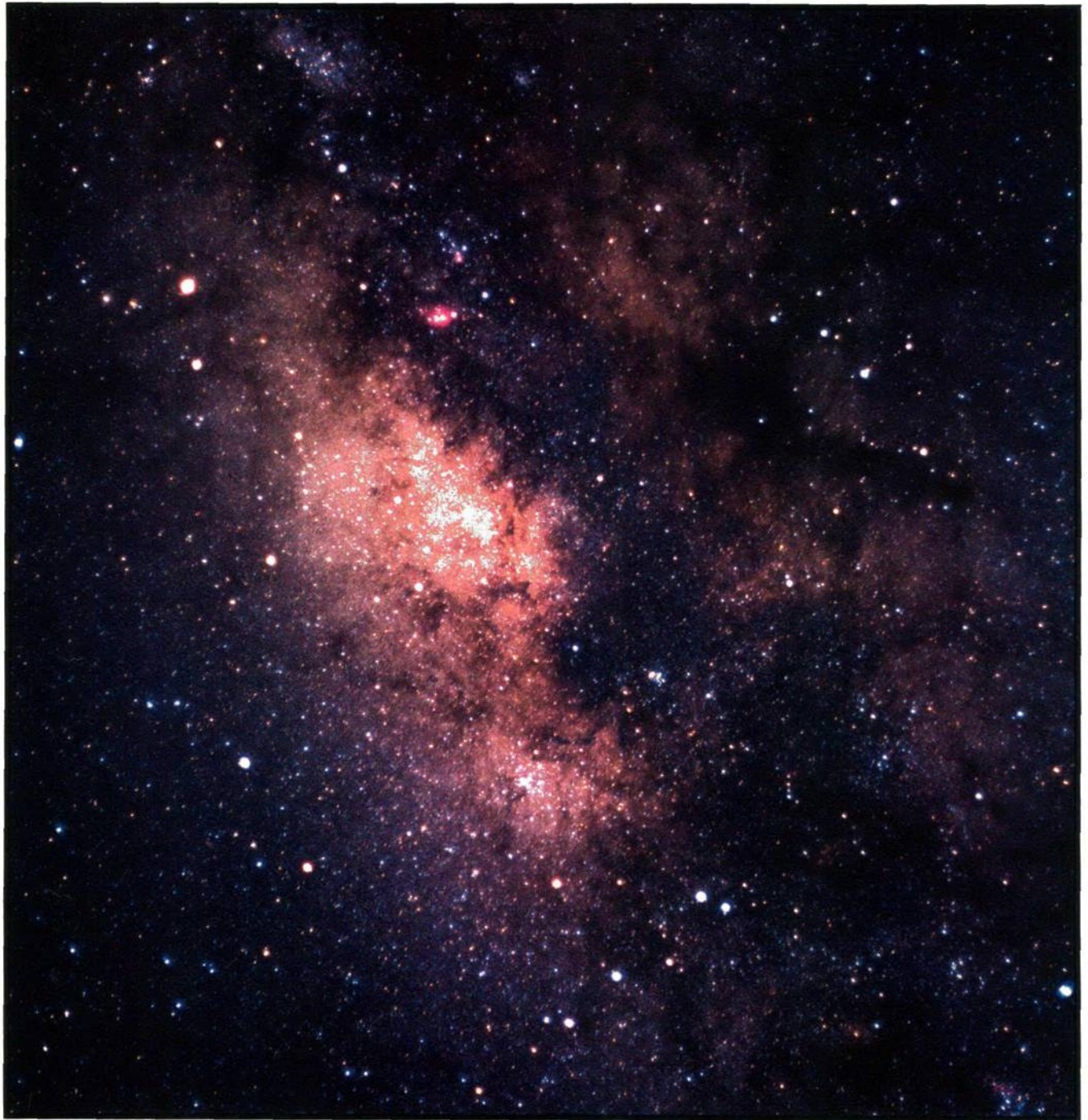
**July 1987**

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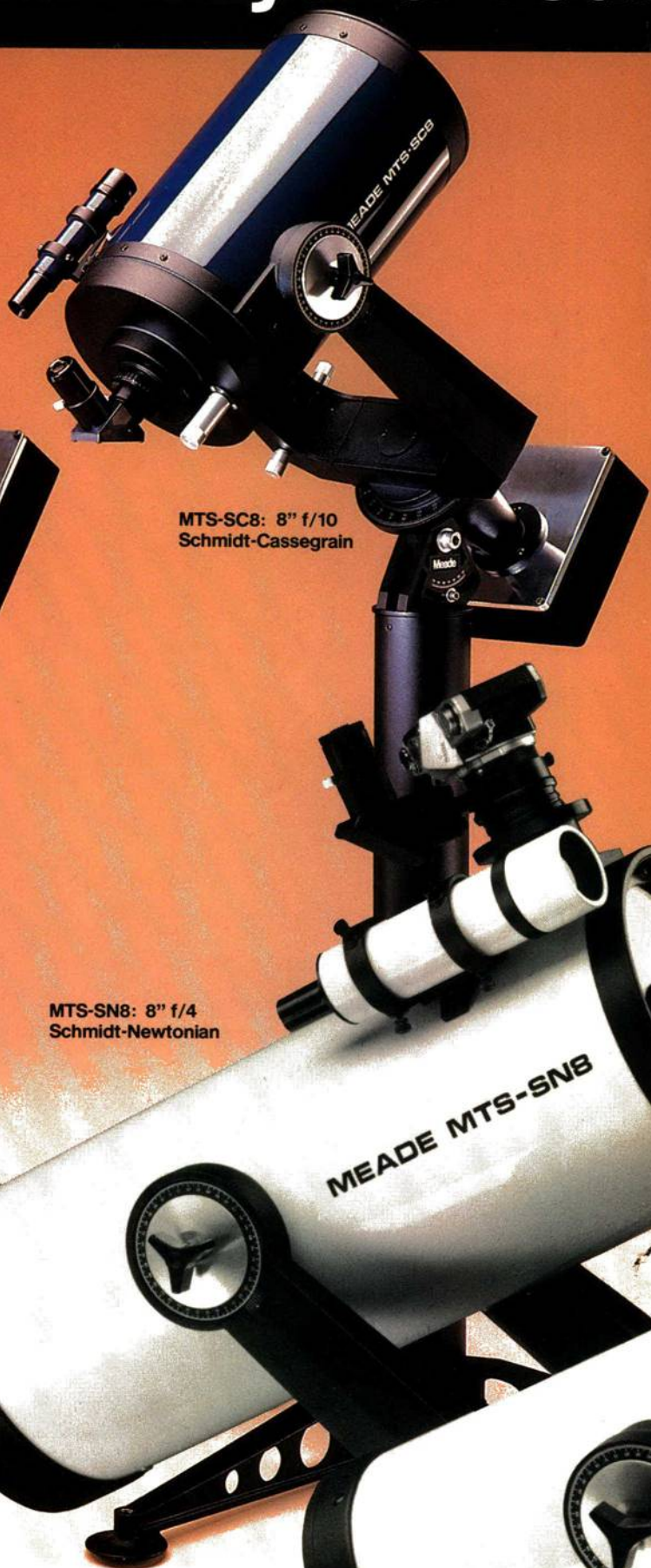
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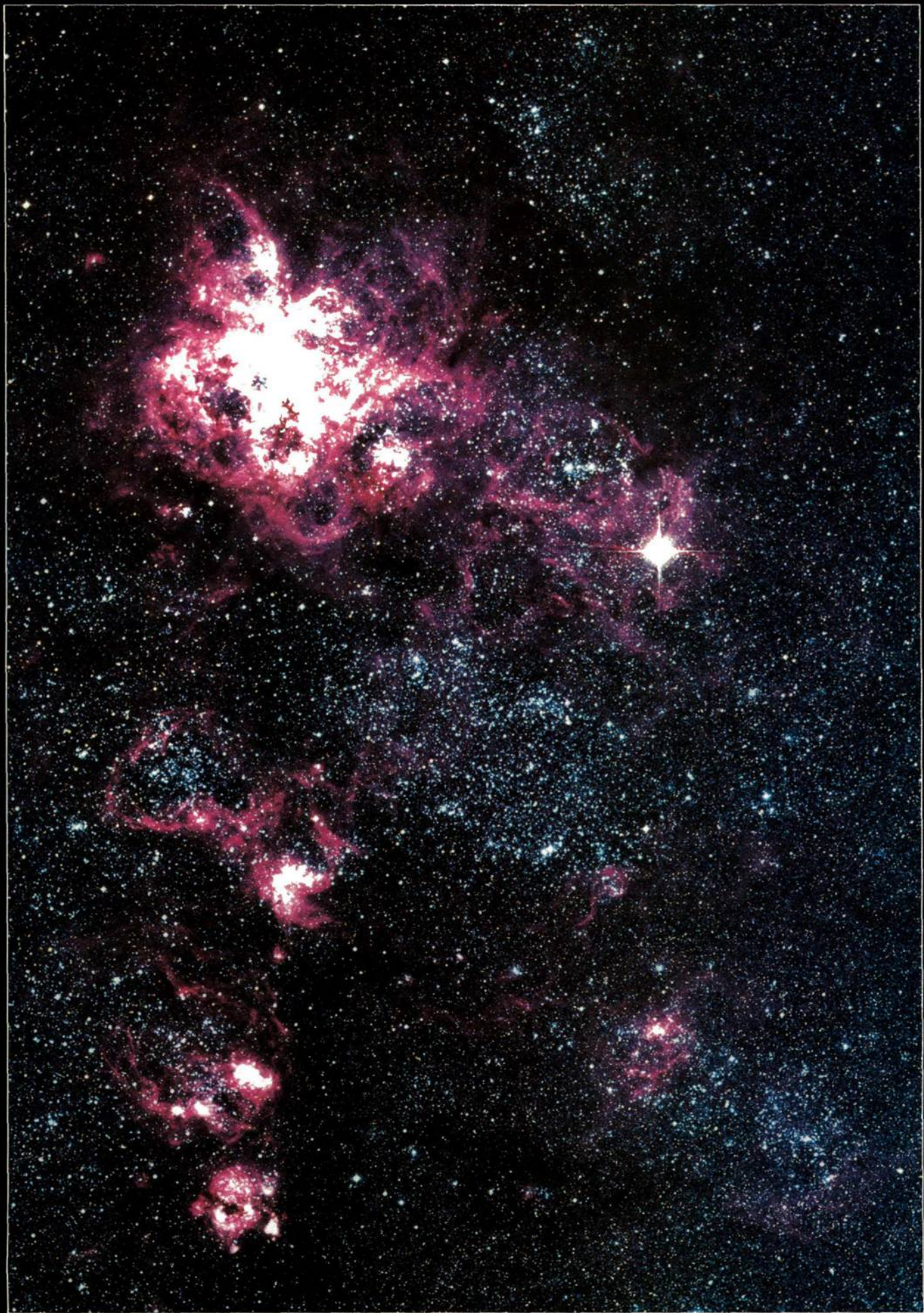
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# ASTRONOMY

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**Cover:** The star clouds of Sagittarius, marking the center of our Galaxy, were captured by astrophotographer Simon Tsang in this magnificent photograph taken from Chile. He used Fujichrome 1600D slide film, a 50mm lens at f/1.8, and a 3.5-minute exposure. Opposite page: Supernova Shelton 1987A shines in the Large Magellanic Cloud four days after its discovery. This color-composite photograph was made with the 1-meter Schmidt telescope at the European Southern Observatory at La Silla, Chile. Copyright © 1987 ESO.

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# Science at McDonald Observatory

Photographs and text by Robert Reeves

*Perched atop Mount Locke in the Davis Mountains of west Texas and armed with three powerful telescopes, a team of scientists proves that cooperation is the key to success in modern astronomy.*

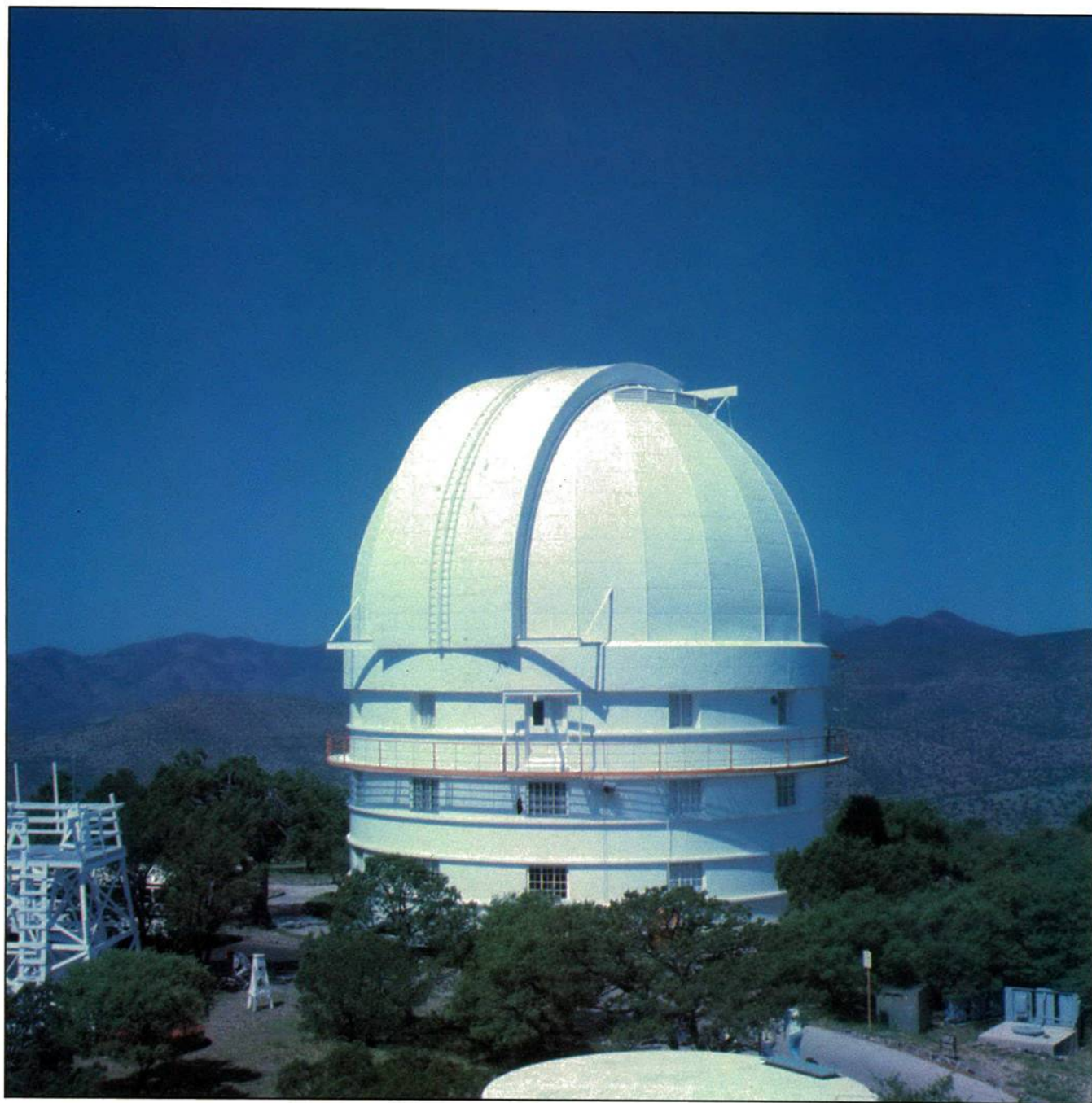


*Astronomers Alex Fullerton, Doug Gies, and David McDavid prepare for a night's observing at McDonald Observatory. During a five-day observing "run" they will be looking at O-type stars, studying the way these hot blue objects expel matter into space.*









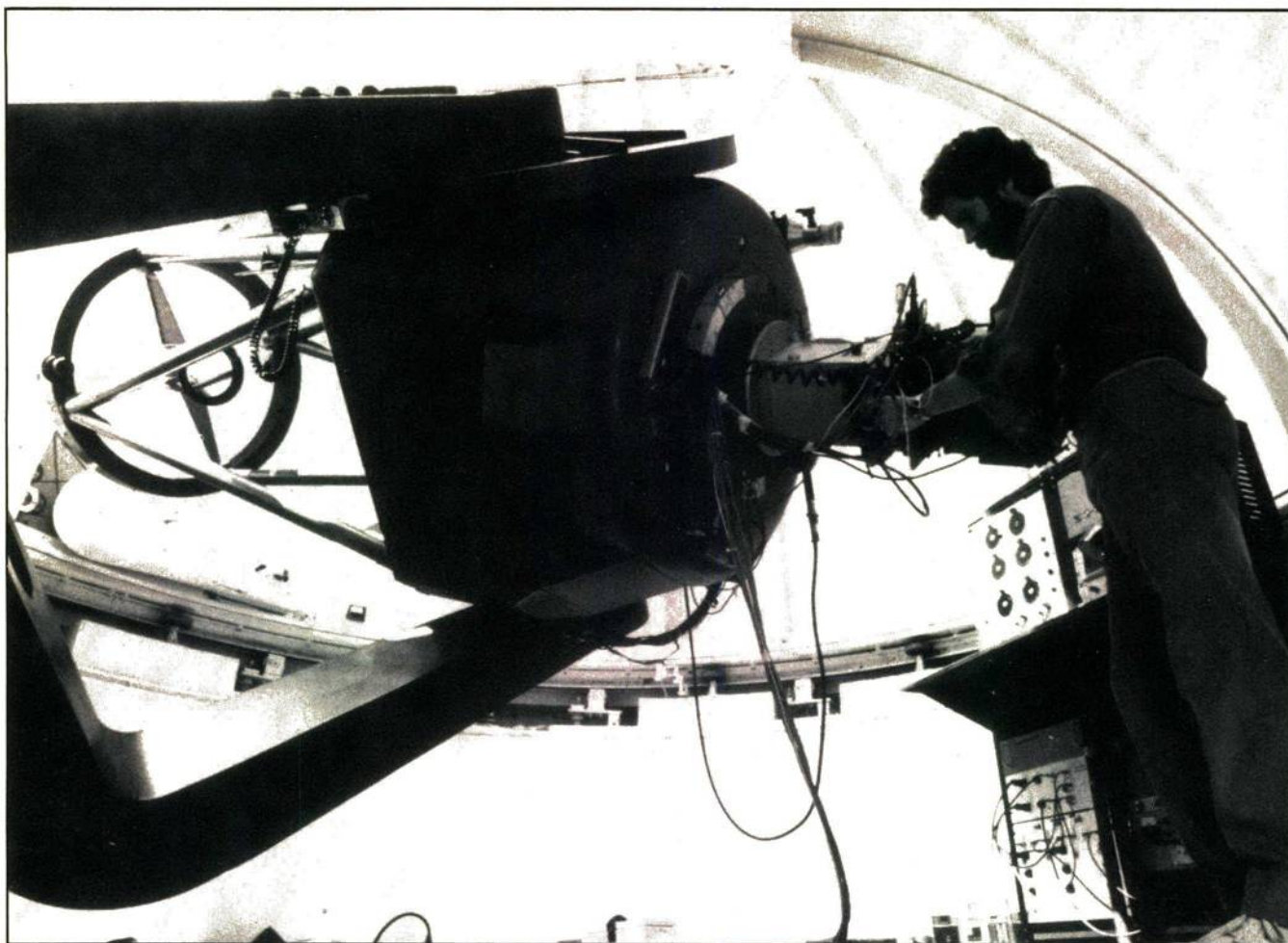
*Above: When it was finished in 1939, the dome of McDonald's 82-inch telescope was surrounded by wilderness. But the observatory is no longer cut off from civilization: its facilities include comfortable housing for visiting astronomers, a machine shop, a swimming pool, an athletic field, and even a McDonald Observatory Fire Department.*

Professional astronomy has changed dramatically in the last few decades. Gone are the days when astronomers hand-guided a monstrous telescope while a glass photographic plate slowly captured starlight. Today automatic guiding mechanisms track the telescope while charge-coupled devices soak up every photon of light from faint sky sources. Electronics and computer-processed imaging have taken over.

One of the half dozen principal American institutions practicing this new astronomy is McDonald Observatory, located on the summit of Mount Locke in the Davis Mountains of western Texas. McDonald lies on an unusual multilayered volcanic remnant, some 6,800 feet above sea level and 170 miles southeast of El Paso. The location offers a very dark sky, which is frequently "photometric," or completely free of clouds and haze. The only nearby town is Fort Davis, a village of 850 people that evolved from an ante-bellum army garrison.

McDonald's start was unusual because it involved astronomers from two widely separated institutions. In 1932 the University of Texas received a bequest of \$800,000, which included the stipulation





that the money be used to build an observatory. The money came from the estate of a wealthy banker from Paris, Texas, whose interest in the stars led him to include the university's astronomy interests in his will. According to a plaque on the observatory grounds, William Johnson McDonald "lived frugally, read science books, and viewed planets through a small telescope." His gift started a major observatory.

At this point the Texans had \$800,000 — enough money for a large telescope — but virtually no astronomy department and little expertise to put a telescope to good use. Curiously, astronomers at the University of Chicago had just the opposite problem: they were expert observers and scientists, but their outpost at Yerkes Observatory in southern Wisconsin was plagued by poor observing conditions. They wanted to observe from a dark sky location, like the one near Fort Davis, that would also allow them to observe more southerly objects. The two groups reached a mutual agreement: the director of Yerkes would run the newly formed McDonald Observatory and both groups would conduct research there.

These days the observatory is run solely by the University of Texas and contains three principal telescopes. An 82-inch reflector, named the Otto Struve telescope in honor of the observatory's first director, was completed in 1939. At that time it was the second largest telescope in the world: only Mount Wilson's 100-inch Hooker telescope was larger. In 1956 a 36-inch Cassegrain telescope was installed, and in 1969 work was completed on a 107-inch reflector.

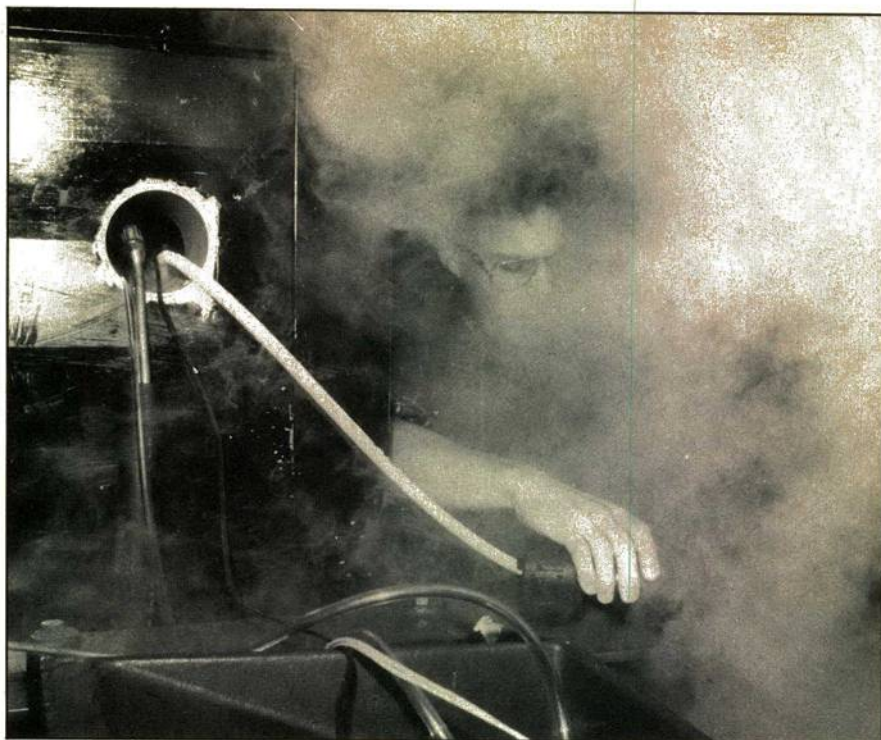
#### **Sampling the New Astronomy**

In August 1986 I traveled to Fort Davis with David McDavid of the University of Texas, drove up to the summit of Mount Locke, and sampled the new astronomy at McDonald. David is a member of a team of scientists studying O-type stars, which are extremely hot, blue

*Gearing up for an "observing run" to study O-type stars, astronomer David McDavid checks the instrumentation on McDonald's 36-inch telescope, the smallest of the observatory's three major instruments. David is one of a team of four scientists working on an O-stars project; he will couple a polarimeter to this telescope and use the device to measure how O stars, which are young and hot, expel matter into space.*



While David McDavid is busy with the 36-inch scope, colleague Alex Fullerton prepares the 82-inch Otto Struve telescope. Nearly hidden by vapors, Alex fills an electronic spectrograph with liquid nitrogen coolant. This will maximize the spectrograph's sensitivity to light and allow Alex to record the signatures of specific chemicals in the light from O stars.



stars burning energy at a furious rate. The team wants to discover whether or not these stars pulsate the way many B stars do. If the O stars do pulsate, the team will know that stars hotter than spectral type B are capable of such activity. If the O stars don't pulsate, they'll define an upper temperature limit at which stars can pulsate. Once the astronomers learn whether O stars pulsate, they'll add a bit of knowledge to the general understanding of stellar interiors. In the words of University of Toronto astronomer Alex Fullerton, another of the scientists involved with the project, "We want to put some constraints on the way O stars work."

Another member of this team who observed during my stay was Doug Gies of the University of Texas. The fourth team member, Dutch astronomer Huib Henrichs, was at NASA's Goddard Space Flight Center in Maryland, where he would use the International Ultraviolet Explorer (IUE) satellite to simultaneously observe the same stars the others watched from Texas. Huib met Doug and Alex at an astronomical conference in Toronto three years ago and joined the observing team because he is intensely interested in these stars. (Huib has studied the ultraviolet spectra of O stars for several years now.) Because the team has been observing O stars, it seems only natural that David, Doug, Alex, and Huib have become known as "The O-Team."

We arrived at McDonald late in the afternoon after a long drive and met Alex and Doug. The warmth of their welcome helped me shake off the numbing effects of the 450-mile drive.

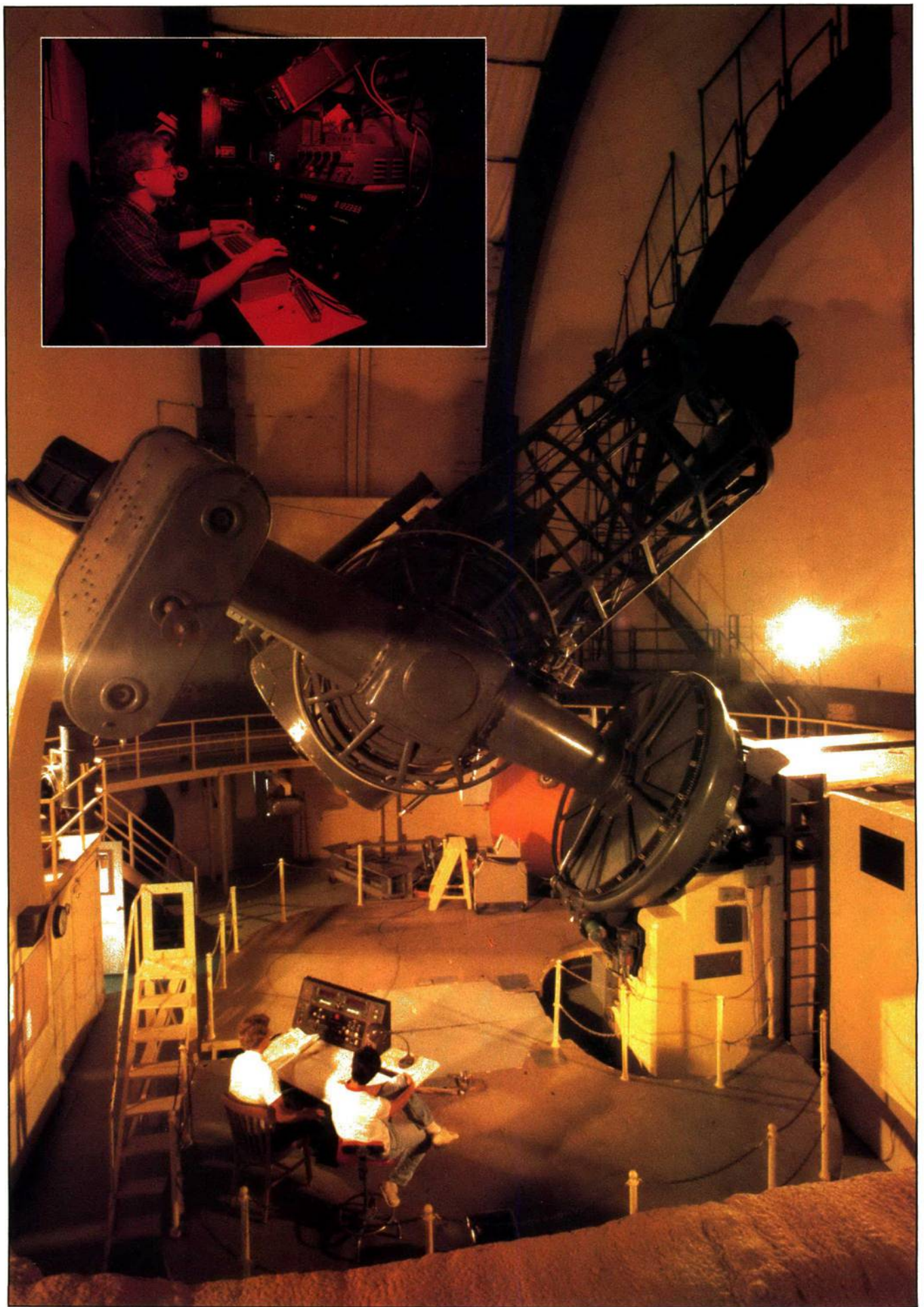
Because they had been observing the previous night, Alex and Doug were just getting up; as I was finishing dinner, they began their breakfast. When I asked them about their progress so far, Alex merely said that the night had been clear and they had obtained several spectrograms. Lacking any up-to-date know-how about professional spectrograms, I asked Alex if he had developed them yet. From the baffled look on his face I sensed I had committed an astronomical *faux pas*. I found out that spectrograms aren't made on film as they were several years ago; instead, they are exposed onto cooled electronic reticon sensors and stored on magnetic tape.

After this short briefing from my hosts, I had a basic understanding of what they were doing during this observing run. David used the 36-inch reflector, fitted with a device called a polarimeter, to

*Opposite page: Alex will use the 82-inch telescope to record spectra from O stars. By observing how absorption lines in the stars' spectra change locations, he and his fellow researchers can determine how these stars are shedding material into space, a key to understanding how they evolve.*

*Inset: In sharp contrast to the telescope itself, the control room of the 82-inch scope is filled with electronic gadgetry. During a night's observing Alex checks the telescope's operation as a stream of spectral data flashes onto his computer.*







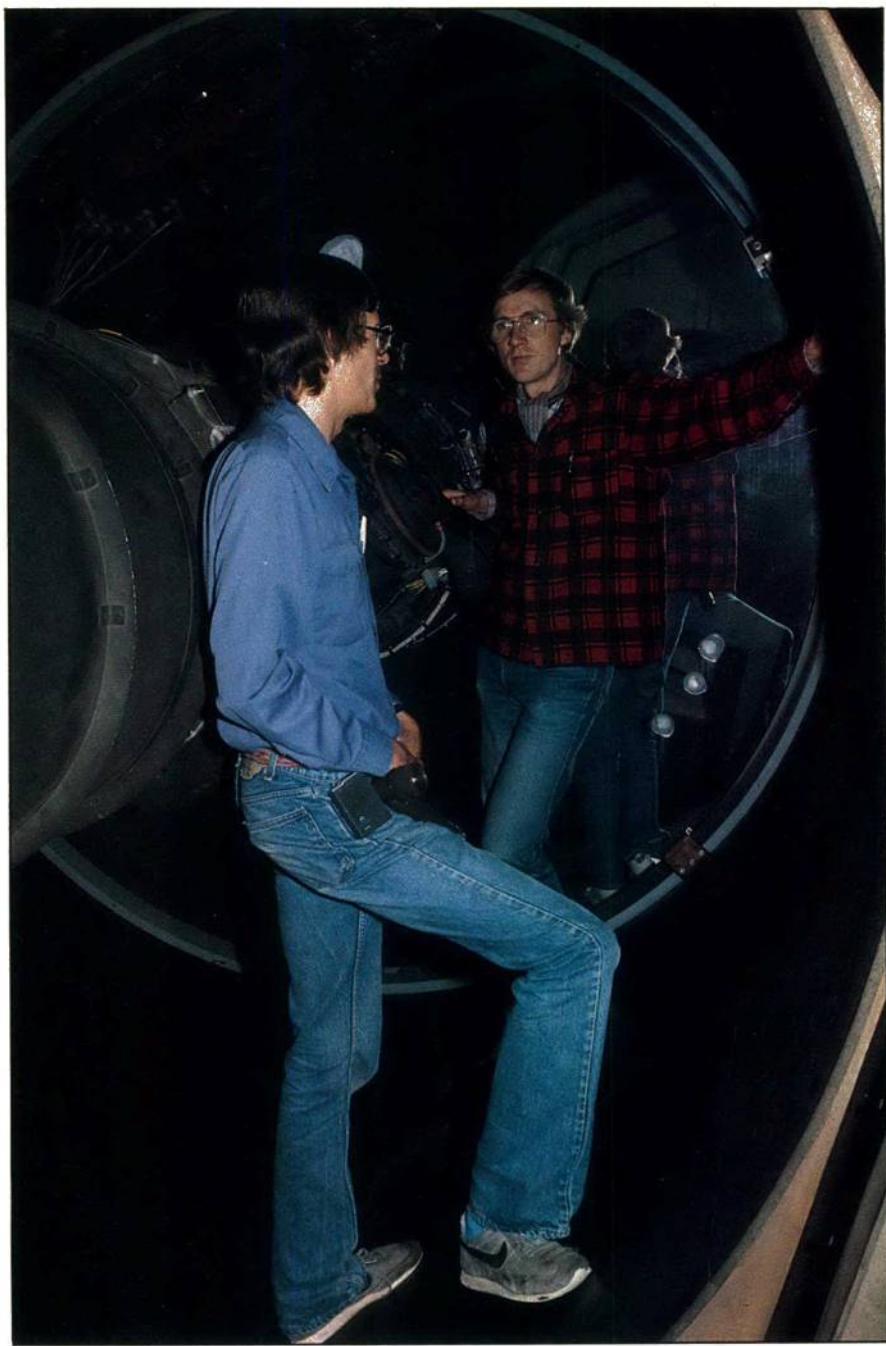


*Above: Completed in 1969, the 107-inch reflector on Mount Locke has since provided data for thousands of research papers. Its massive mounting was recently converted to carry a truss-type secondary mirror mount, which allows astronomers to easily change the mirror's focus from Cassegrain to coude.*

*Right: Doug Gies shows the rainbow of light reflecting off the 107-inch telescope's spectrograph diffraction grating, a glass sheet etched with parallel lines that diffract light into a spectrum. Doug will use this device to collect spectra of the O stars while Alex Fullerton takes spectra with the 82-inch scope.*







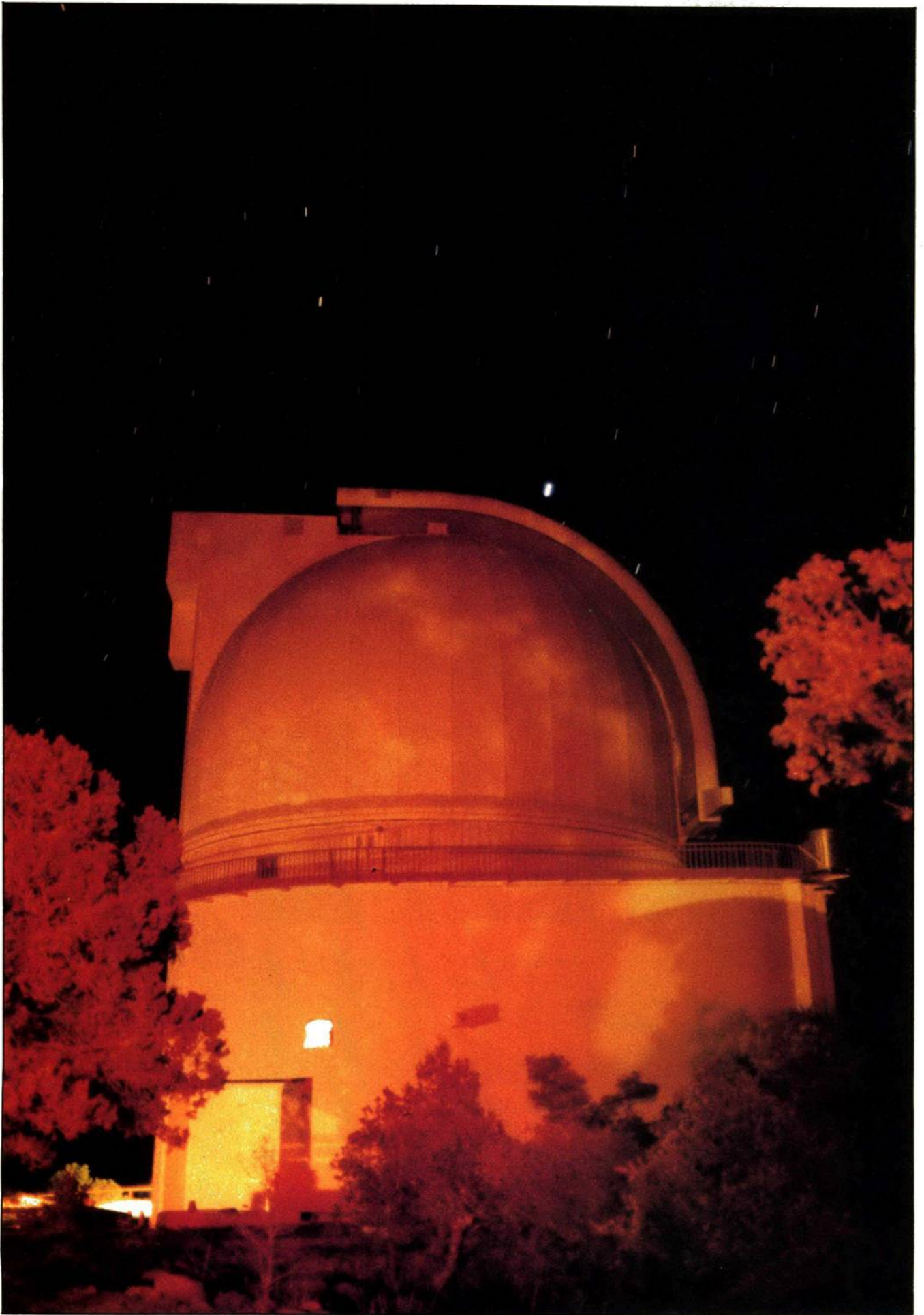
measure the degree of polarization, or orientation of the wave motion of light, from different stars. An O star may well expel material that forms into a shell around the star. If this material is not distributed symmetrically, the light coming from the star will be polarized by free electrons in the shell.

David studies the nature of material streaming off these stars by examining the degree of polarization of the stars' light. Alex uses the 82-inch Struve telescope, coupled with a spectrograph, to study a small bandwidth of light from these young, hot, O-type stars. He examines this light in the reddish 6563-angstrom hydrogen-alpha line. Doug simultaneously studies the stars as they appear in the bluish 4686-angstrom helium line with the 107-inch telescope. Meanwhile, from his outpost at Goddard, Huib observes the O stars in the ultra-violet part of the spectrum.

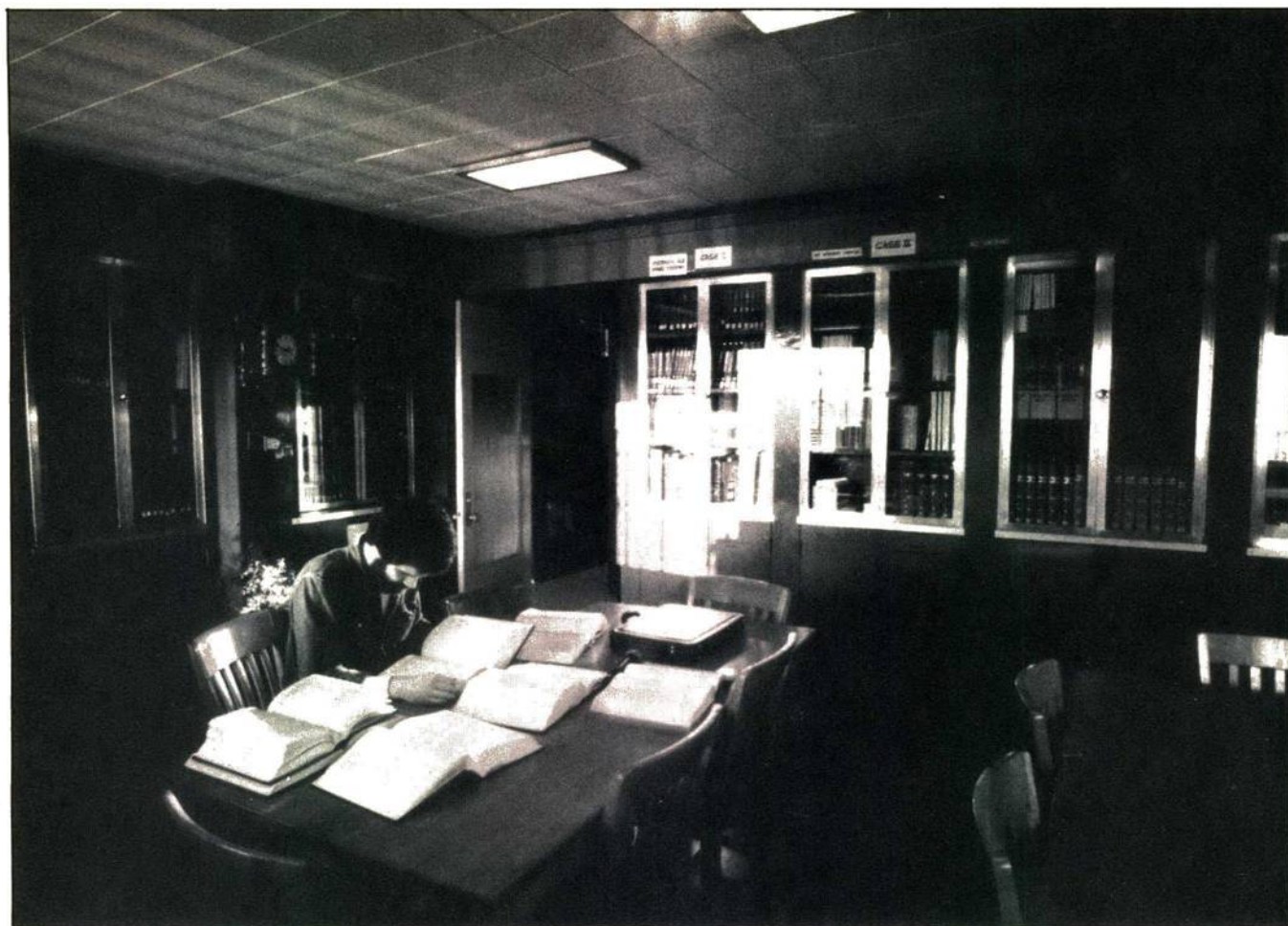
For their observing run Alex and Doug had chosen three O stars between six and ten times more massive than the Sun: Lambda Cephei, 19 Cephei, and 68 Cygni. All three are bright enough to leave distinct spectral signatures, and they are well-placed for observing

*In the late 1960s a frustrated observer walked into the 107-inch dome, pulled out a handgun, and fired three shots into the telescope's mirror. Technicians simply ground the holes to avoid further cracking, and the telescope lost only about 2 percent of its effectiveness. Here night assistant Mark Richards (left) and Doug Gies reflect on the night ahead inside the 107-inch tube; the bullet holes are visible behind them.*









during August nights.

Alex explained that he was trying to prove the existence of "non-radial pulsations" in O-class stars, and that Doug was searching for variations in the stellar winds of these stars. Together, they are trying to show a connection between the two phenomena.

I asked Alex what he meant by nonradial pulsations. He used his breakfast orange to illustrate the answer. Peeling the orange so only vertical strips of skin were removed, he explained that the theoretical model for O stars predicted the stellar surface should be heaving and undulating up to 5 percent of the star's radius, so it resembled the uneven surface of the partially peeled orange. The star's surface would not heave uniformly at any given moment: some parts would rise while other parts fell, as demonstrated by the now half-naked orange. Thus, the pulsations would be nonradial, or not all in the same direction.

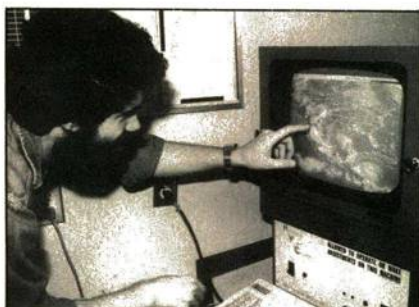
In theory these pulsations should have an effect on the spectra of these stars. Indeed, the exposures Doug and Alex have been accumulating show that changes occur in the spectra of these stars over time periods ranging from one hour to one day. This change in an object's spectrum is called a "line profile variation" and is expected if a star is nonradially pulsating. Line profile variations are visible as "bumps" on various absorption lines that change place over time, which has earned them the nickname "traveling bumps."

The heaving of the star's surface during the pulsations suggests that the stellar wind from these young giant stars should come off in patches or clumps instead of continuously. Ultraviolet data from the IUE satellite confirm that the winds are behaving in a nonuniform fashion. And, if the stellar winds are coming off in this fashion, they will polarize the light from the star's surface because of free electrons in the star's circumstellar shell. Should this be the case, David would

*Above: McDonald Observatory contains an extensive library of astronomical materials for cloudy nights and daytime research. David McDavid checks research papers on O-type stars.*

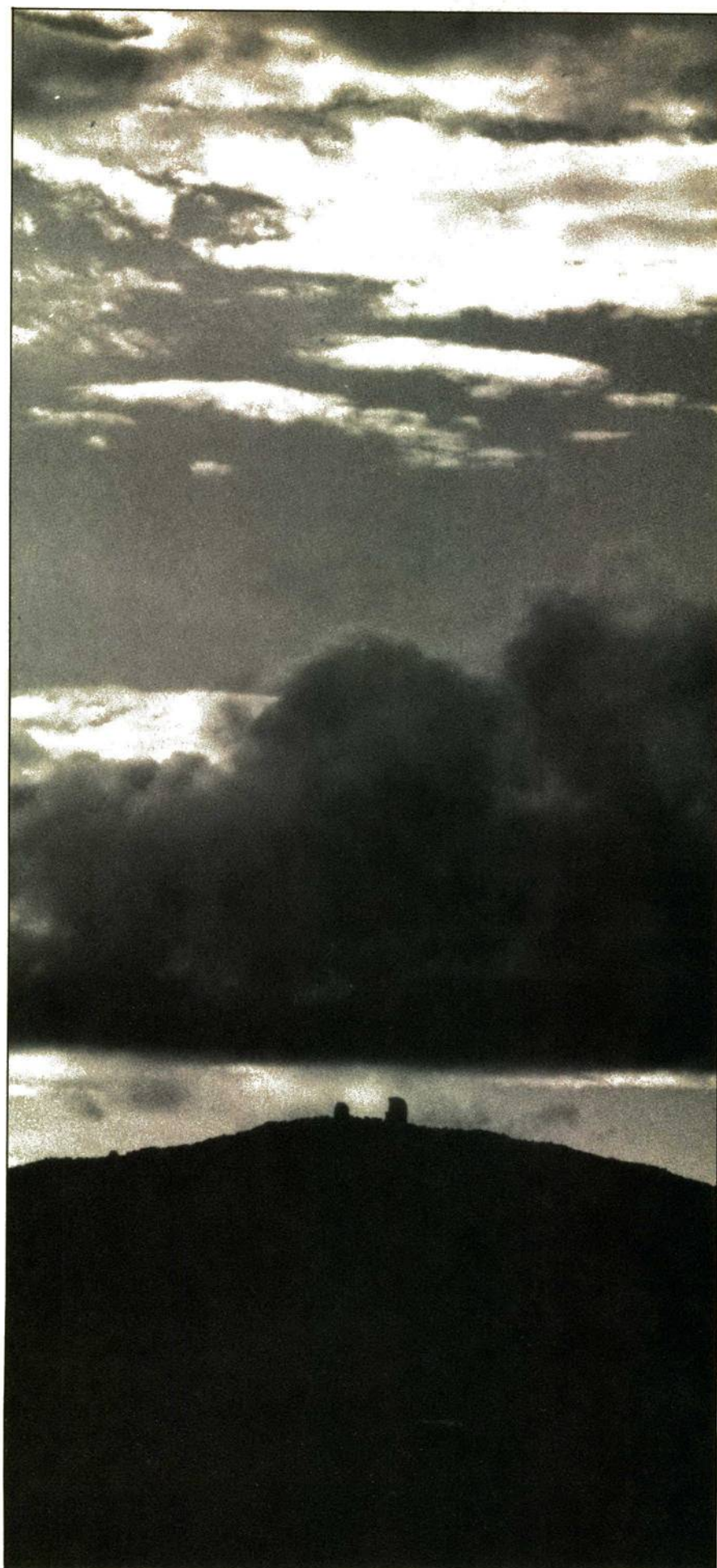
*Opposite page: Stars trail over the 107-inch telescope's dome, illuminated in this photo by the lights of a nearby truck.*





*Above: Astronomers reserve observing time on big telescopes far in advance. Weather conditions, however, change continually up to and throughout a night's observing. On one cloudy night, David McDavid checks the progress of a front on a television monitor as it moves through west Texas.*

*Right: The domes of the 82-inch and 107-inch telescopes sit idle as clouds hover above. With all of the planning, knowledge, and equipment involved in professional astronomy, luck still plays a major role in the outcome of research.*







*Is the light from O stars polarized? Do O stars undergo pulsations periodically? Do they throw off uneven blotches of star stuff into space? Although the O-Team didn't quantitatively answer these questions during their five days at McDonald, they did contribute pieces of data that will eventually solve the puzzle of O stars.*

detect the polarization with the polarimeter on the 36-inch telescope.

#### **New Ways of Observing**

Because individual observers cannot gather enough varied data before certain types of objects, like O stars, change, observing an object simultaneously in different areas of the spectrum is becoming a popular tactic in professional astronomy. However, the more observers and instruments involved, the greater the chance of something going awry. A year ago when the O-Team mounted a similar stellar assault, the ground-based observers at McDonald had twelve clear nights to collect their spectra. In Earth orbit, however, control of IUE was lost because a gyro failed aboard the satellite, and the ultraviolet data were lost.

This August the O-Team had full control of the IUE satellite. But a day after the astronomers arrived at the observatory the weather deteriorated. Even though good ultraviolet data were coming from IUE, the visible light observations were clouded out, and late on the second night rain began to fall. The rain continued for three days. During that time I talked to the astronomers, visited the telescopes, and read books at the observatory's library. When the rain finally stopped during the evening of the fourth day, Mount Locke was encased in a thick fog.

But my final night at McDonald turned promising at sundown as the clouds began to dissipate. By 11 p.m. the sky had cleared and the astronomers leaped into action on all three telescopes to make up for lost time. As Doug and Alex exposed spectrograms with the large telescopes, David successfully recorded data indicating that the light from the target O stars was indeed polarized, which implied the existence of nonradial pulsations.

As I stood in the dim glow of the LED displays and CRT screens monitoring the polarimeter on the 36-inch scope, I felt a pang of nostalgia for the old days before astronomers turned to electronics. But technology relentlessly marches on, and our knowledge of the universe has expanded greatly because of it.

No great discoveries were made during this observing run, but more bits of information accumulated in the ever growing "data dump" of science. As I left McDonald, I realized that under the direction of astronomers like David, Doug, Alex, and Huib, the process of deciphering the universe will continue at a record pace.

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*Robert Reeves is an active amateur astronomer and astrophotographer living in San Antonio, Texas. Reeves is a frequent contributor to Photography in Astronomy.*



09\*

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1. *Review*

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**This page: Chalk drawings of prominences by Carl Frederic Fearnley, September 11, 1873.**  
**Opposite: A tall (90,000 kilometers) prominence photographed May 32, 1983, in H-alpha light.**



# Old and New Views of Solar Prominences

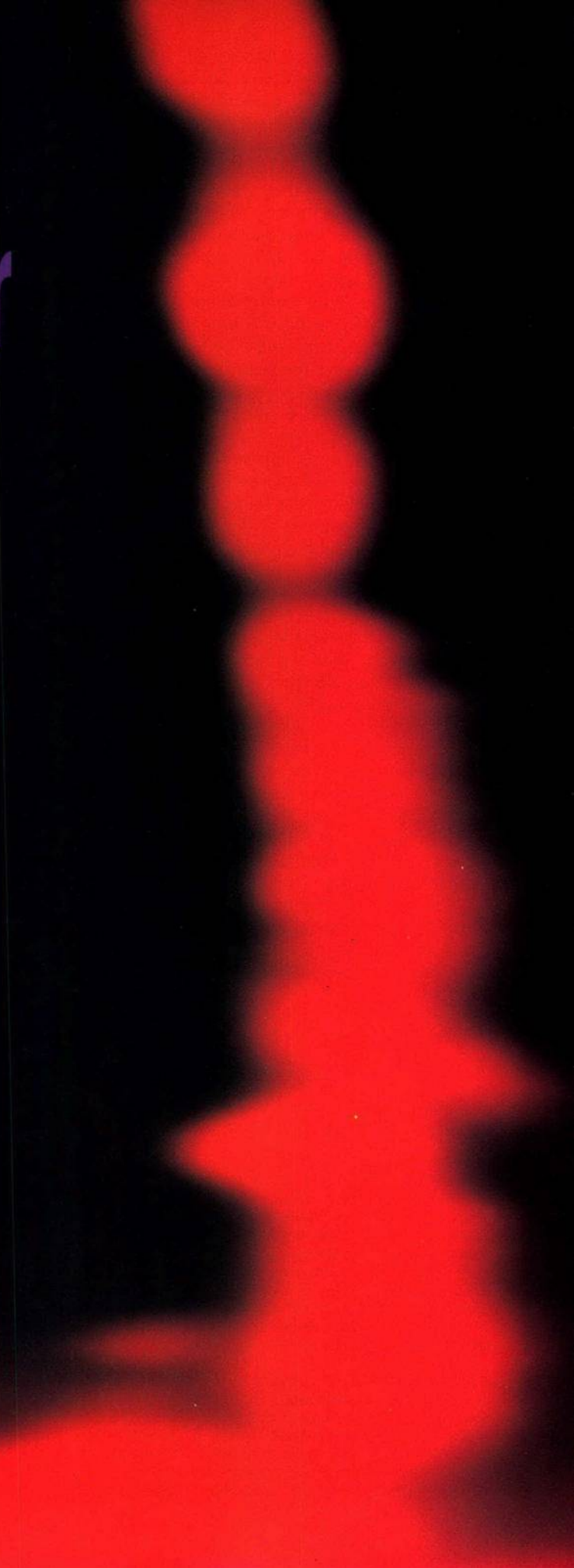
by William Livingston, Oddbjørn Engvold,  
and Eberhart Jensen

Observatory archives, like the contents of a forgotten trunk in some dust-covered attic, sometimes contain records made valuable by the passage of time. While rummaging through some papers stacked on a high shelf at the Oslo Institute recently, we came across a series of beautiful prominence drawings made over a century ago by Carl Frederic Fearnley, an astronomy professor at the University of Christiania (now Oslo) from 1863 to 1890.

Though Fearnley had only the simplest of optical aids at his disposal, his drawings capture the intricate features of prominences in a way that equals some of the best modern photographs. Altogether fifty of his drawings have been preserved.

Fearnley was a meticulous observer as well as a skilled artist. His prominence work was carried out during 1872 and 1873 with the 15-centimeter (6-inch) refractor at the university's observatory. Attached to his telescope was a small spectroscope that employed a composite prism, which dispersed the sunlight passing through a narrow, rectangular slit. His observations with this spectroscope utilized the effective eye-brain sensor package: the eye as a detector accommodates a wide range of light intensity, while the brain filters good seeing images from bad. Fearnley's spectroscope clearly displayed Doppler shifts caused by internal motions of the prominence material, which gave Fearnley some clues about the density and dynamics of prominences.

Fearnley searched for prominences by scanning outside the solar limb while simultaneously keeping the spectroscope's slit tangentially aligned to the limb. He would





initially observe with a narrow slit setting to keep the intensity of the sunlight low so he could comfortably search the field without being blinded. Once he had located a prominence, he opened the slit and moved the image across the slit for thorough examination.

### The Discovery of Prominences

From the moment they were discovered, solar prominences called attention to themselves by their color. During the total eclipse of May 13, 1733, the Swedish astronomer Birger Wassenius noticed "red flames" outside the Sun's limb. Unfortunately, his observation was not widely circulated: even the corona, the tenuous outermost atmosphere of the Sun, received scant attention. Detailed studies of these telling features would wait for yet another century. There is no reason prominences and the solar corona, which are not that difficult to observe during a total eclipse, weren't more widely noted at the time. Perhaps the darkness of totality somehow rendered the astronomers unreceptive to these features.

During the widely observed eclipse of July 8, 1842, these "red flames" were unequivocally rediscovered by astronomers in southern Europe. At practically every total solar eclipse since then, prominences have been subjects of both wonder and scientific study.

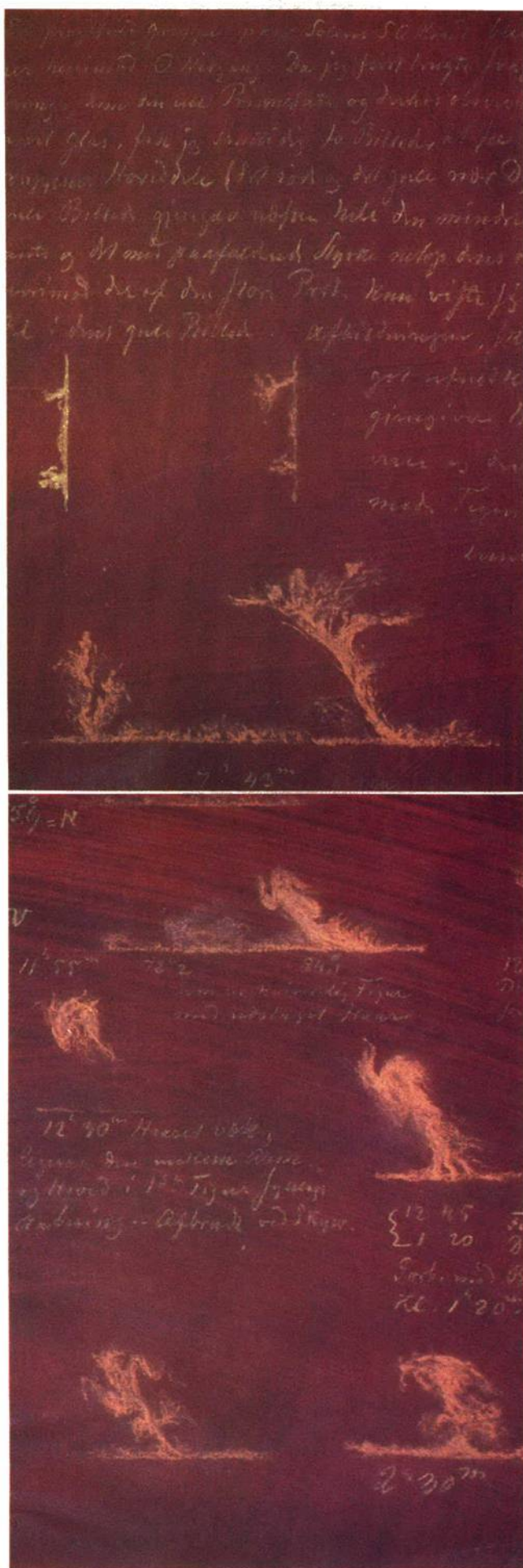
### Spectral Purity

Prominences are vivid red; no other astronomical object has a color so spectrally pure to our eyes. This is because a prominence's light arises from photons emitted by hydrogen atoms in the Balmer-series spectral line of H-alpha ( $H\alpha$ ) at 6563 angstroms, which is in the heart of the red spectrum. When prominences were first visually examined with a spectroscope (instead of their spectral lines being examined), several other less intense colored images were revealed. For instance, there is a weak yellow image at 5876 angstroms caused by helium, a blue image from the H-beta ( $H\beta$ ) line at 4861 angstroms, and a violet image at the extreme violet end of the visual spectrum emitted by singly ionized calcium at 3933 and 3967 angstroms. To modern day instruments, which are sensitive to a wider range of wavelengths than our eyes, the violet images are as bright as H-alpha light. If our eyes were more sensitive at violet wavelengths, prominences would look purple.

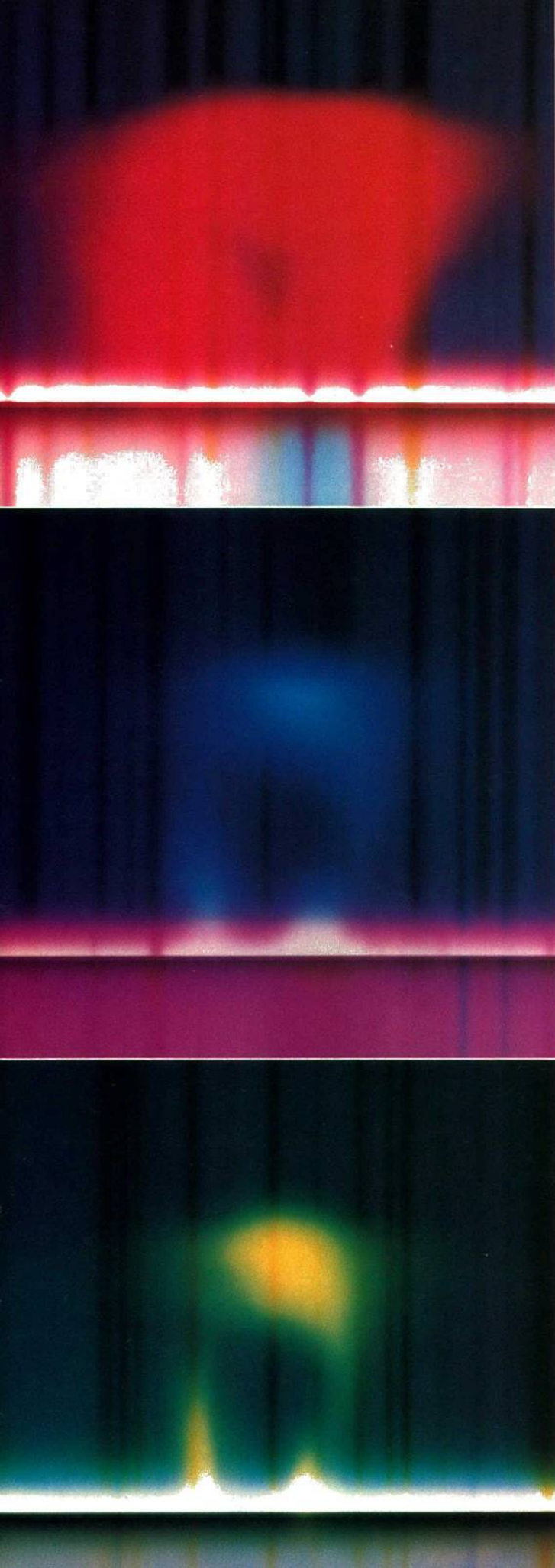
Most suitable for Fearnley's work were the bright prominence emission lines of H-alpha in the red and helium in the yellow. His drawings were faithful to the colors of the prominences: he used red chalk for H-alpha and yellow chalk for helium. The dates and times for the observations, along with his comments on weather and

**Top:** In these drawings made August 1, 1873, Fearnley discovers that helium and hydrogen images of the same prominence differ in appearance. Near the bottom is an H-alpha sketch of "a magnificent pair on the S limb which I became aware of just before sunset." In less detail the upper vertical images compare helium (left) with H-alpha (right). He points out that the helium image fails to reproduce the higher parts of the larger prominence seen in H-alpha. Because the helium line requires a higher temperature for excitation than H-alpha, presumably this larger prominence is cooler.

**Bottom:** These drawings, made August 15, 1873, show that then, as now, some prominences are more interesting than others. Clouds frustrate Fearnley in his observations of "a female figure with her hair hanging loose" (top). At 12h06m local time he writes, "The upper part clearly more melted together." And at 12h30m (middle left) that the "hair dissolved as well as the opening between the arms and head as seen in the first drawing — thereafter clouds."







Three photographs at different wavelengths of a prominence observed on the southeast limb February 3, 1982. The photo at the top is in H-alpha light; the middle photo is in H-beta light, and the photo on the bottom was taken in helium. Velocities up to 200 kilometers per second are evident by the width at the top of the prominence, although the narrow structure in helium indicates the gas can be quiescent at places of high temperature. The band of color containing absorption lines seen below each prominence is the spectrum of the Sun's disk. The sharp edge between the prominence and the disk spectrum was caused by a card that was placed over the disk during exposure of the prominence. The card was subsequently removed for a brief exposure of the disk.

what we call "seeing," were written in pencil alongside the drawings. (Some of these notes are difficult to decipher.) These drawings were made merely twenty years after the German-Russian astronomer Friedrich Georg Wilhelm von Struve had established that prominences were of solar origin. One school of thought prior to von Struve's work placed prominences in the lunar atmosphere! This means there were few, if any, ideas about how prominences would look.

### Modern Views of Prominences

Most modern spectrographs no longer employ a prism to disperse light but use a diffraction grating, a sheet of glass or polished metal mirror etched with thousands of machine-ruled lines per centimeter. Light passing through or reflecting from such a grating is diffracted, or bent, around the edges of these lines. When this diffracted light is focused, it yields a series of spectral lines for each resolvable wavelength present in the incoming light. Some of this light passes directly through (or from) the grating, but some of it is diffracted into spectra on either side of the undeviated light. These are called first-order spectra. Farther away from the first-order beams are fainter, more dispersed spectra called second-order spectra. And beyond these orders lie overlapping spectra of the third order, fourth order, and so on.

Astronomers generally utilize the first- and second-order spectra because these beams are brighter than the higher orders. However, for solar spectroscopy the higher order spectrum is preferred because it is more spread out than the lesser order beams, so more spectral lines can be resolved. In some cases the spreading enlarges one angstrom, which is equal to one ten-billionth of a meter, to one centimeter in length!

When we make prominence observations at Kitt Peak National Observatory or Sacramento Peak Observatory, the eye is replaced by more sensitive detectors such as high-speed film or charge-coupled devices. Still, in the course of setting up the instrument on a spectrum line, we view prominences in the same manner Fearnley did. Consequently, our attention has been drawn to the beauty of the spectral colors and the structure of the images we see there. By placing a color film cassette at the focus of the spectrograph, we recorded the spectra accompanying this article.

One advantage of color film is that multiple orders can be exposed simultaneously and then later separated by filters after the film has been developed. This works, provided the wavelengths of the orders match the tricolor dyes of the film. For instance, H-alpha in the third order is exposed in the red layer, and violet calcium at 3933 angstroms in the fifth order shows up in the blue layer. These two lines fall about one centimeter apart on a single frame taken with the Kitt Peak McMath spectrograph. If H-alpha is positioned in the fourth order, we find the iron



**Below:** This conventional image of a quiescent prominence, photographed in the light of calcium (3933 angstroms), has been color-coded to indicate line-of-sight motions. Red indicates gas receding from the observer and blue indicates gas approaching the observer. A study of the motions with time shows the motions appear to be random and not oscillatory or systematic in any way that can be readily understood.

line — at 5250 angstroms in the green fifth order — lying in the same position. This iron line splits in the presence of a magnetic field, which allows measurement of the field strength below the prominence. Also recorded on the frame will be the blue line at 4375 angstroms in the sixth order. All these lines can be studied independently by viewing the film transparency through appropriate filters.

To make our photographs, we positioned the slit of the spectrograph perpendicular to the solar limb, cutting across the disk, the chromosphere, and out through the prominence. The varied hues in the disk spectra — the band of color seen below the prominences in the photographs — follow the rules for the additive mixing of colors. For example, the disk component of an H-alpha prominence picture is the superposition of red, green, and blue orders. But, because the red is missing in the H-alpha line (i.e., absorbed on the disk), we get the combination of only green and blue hues, or cyan. A green absorption line looks magenta because it is composed of red and blue colors, and a blue absorption line appears yellow because it is a mix of green and red.

#### **What Prominence Spectra Tell Us**

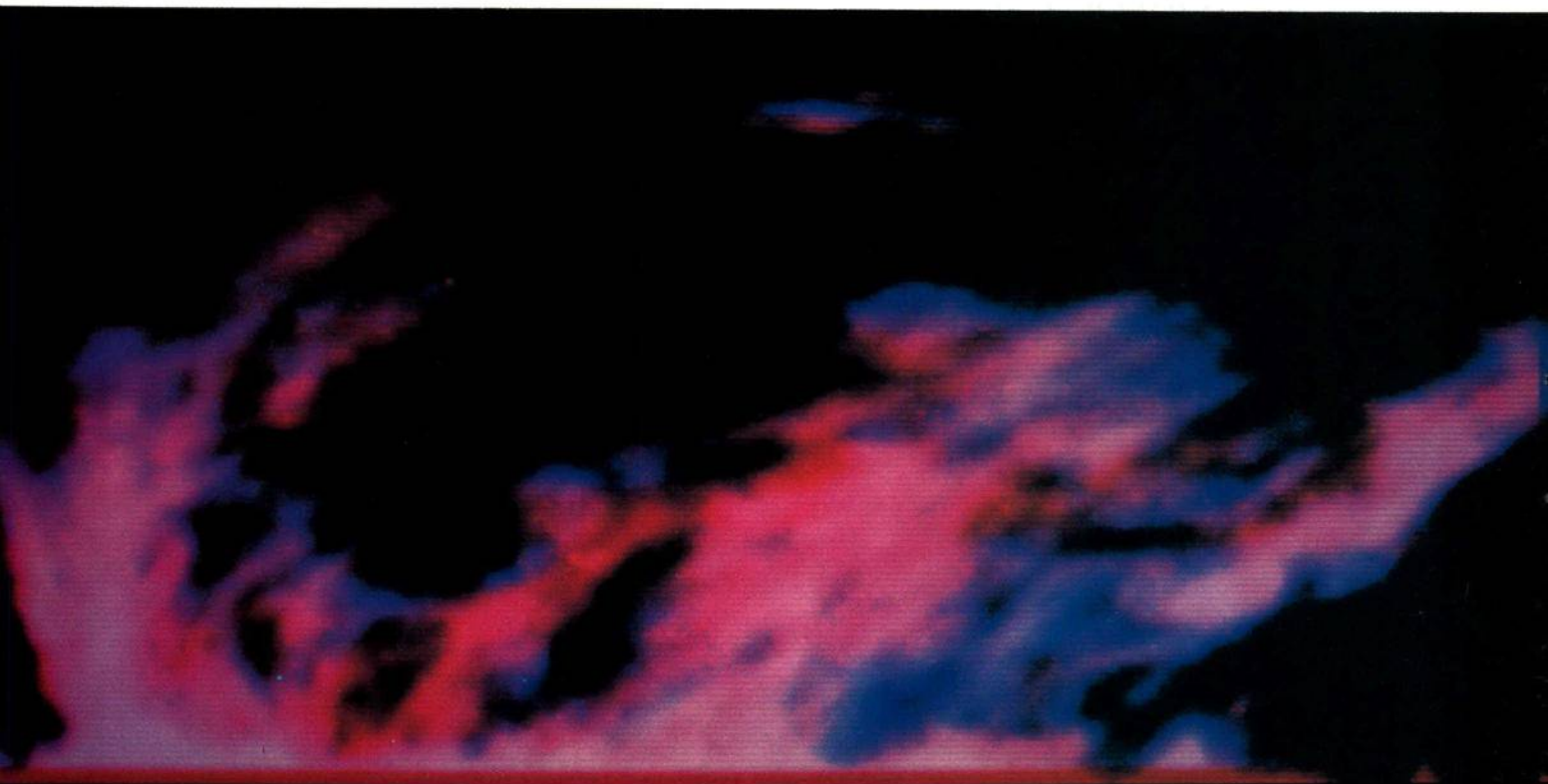
The width and strength of line emission from prominences imply that the gas temperature is about 7,000 Kelvins. The gravitational pull at the Sun's surface ought to squeeze a 7,000-Kelvins atmosphere into a layer with an apparent thickness of one arcsecond. Yet prominences can extend several arcminutes above the Sun. The reason this happens is that magnetic fields support the partly ionized prominence gas, holding it up despite the pull of gravity.

Most of the motions we see in prominences are connected with these magnetic fields. When eruptions occur, gas moving along our line of sight at high velocities reveals its direction by the shift of its spectral lines with respect to a standard laboratory spectrum. This phenomenon is known as the Doppler effect. Lines from the prominence that are shifted toward the red end of the spectrum indicate gas receding from Earth; those shifted toward the blue end indicate approaching material. At other times the turbulent motions of atoms in the gas moving toward and away from Earth smear or broaden spectral lines. Still, some prominences are relatively stationary and produce sharp lines, and we may wonder how matter is fed into them without causing significant radial motion. We also wonder how relatively cold prominence gas can coexist with the surrounding million-degree corona. Theorists believe that the magnetic fields providing physical support of the prominence also act as shields against any intruding hot plasma.

When they saw the photographs of the color spectra of prominences, our friends and colleagues responded favorably, as if the pictures were an art form. Add to these spectral "paintings" the scientific knowledge of the plasma motions, and we have pleased both the eye and mind. More sophisticated observations of prominences are regularly performed: ultraviolet images from spacecraft reveal high temperature structure, and the amount of polarization tells us about the role of magnetic fields. But Fearnley's one-hundred-year-old method remains a valid way to study how prominences evolve while appreciating the aesthetics of science.

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*William Livingston is an astronomer at the National Solar Observatory in Tucson, Arizona, and one of the designers of the 1.5-meter McMath solar telescope at Kitt Peak. Oddbjorn Engvold and Eberhart Jensen are both astronomers with the Institute of Theoretical Astrophysics at the University of Oslo, Norway, and have a long-standing interest in prominences.*







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# ASTRONOMY Forum

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## The Making of *Uranometria 2000.0*

Most star atlases are awkward for amateurs to use in the field because the maps are too large. A convenient-sized atlas like *Webb's Atlas of the Stars* is not much of an alternative, because it contains no deep-sky objects and is hopelessly out of date.

When *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi is published this summer by Willmann-Bell, Inc., amateur astronomers will have a star atlas that is both convenient to use and covers the sky comprehensively. *Uranometria 2000.0* is a two-volume atlas containing 473 overlapping charts. It is comprehensive: 330,000 stars and the entire *Revised New General Catalogue* have been computer plotted and 10,300 additional nonstellar objects have been plotted by the hand of Tirion. This is the first general purpose atlas to include the entire *RNGC*, which gives Dobsonian owners their first guide to these objects.

*Uranometria 2000.0* was named after *Uranometria*, the first "modern" sky atlas published by Johann Bayer in 1603. The title was chosen because Lovi thinks *Uranometria 2000.0* is as significant for our day as Bayer's star atlas, the last atlas published before the invention of the telescope, was for his day.

The new *Uranometria*, plotted for the epoch 2000.0, has been in the works since 1983 and is the product of Tirion and Lovi, two celestial cartographers, and Rappaport, an expert with computerized stellar databases.

Wil Tirion, famous for *Sky Atlas 2000.0*, is a graphic artist and designer who started plotting star maps "just for my own pleasure." His interest in celestial cartography began when he was about ten: he compared the star maps in a book his father owned with the sky and found the maps

weren't accurate. Tirion also drew and labeled the Star Dome maps for *ASTRONOMY*.

George Lovi, columnist for *Sky & Telescope Magazine* and a planetarium lecturer and program developer, has been interested in celestial cartography for most of his life. He drew and labeled the monthly star maps for *Sky & Telescope* and has developed a three-dimensional hand-held planetarium and several planispheres.

Barry Rappaport was encouraged to explore the computer plotting of star atlases by Dr. C. Bruce Stephenson at Case Western Reserve University in Cleveland, Ohio, when Rappaport was studying astronomy there. Rappaport is currently on educational leave from the Jet Propulsion Laboratory, where he did computer analysis and programming for the Deep Space Network and later worked with computer graphics simulation and modeling.

Originally, *Uranometria 2000.0* was to contain 160 charts. Tirion would plot the stars and nonstellar objects and label the charts by hand, which would have taken about five years. Because Tirion was tied up with other projects, he didn't begin drawing the charts right away.

Meanwhile, Lovi and Perry Remaklus, president and publisher of Willmann-Bell, Inc., in Richmond, Virginia, researched star atlases of the past at the U.S. Naval Observatory Library. The research was later gathered together in an essay by Lovi, "Uranometria Yesterday and Today," which appears at the front of the atlas.

"I couldn't help perusing the wealth of old atlases in far more detail" than was needed for the design of *Uranometria 2000.0*, Lovi said. "Since I was so interested in the subject, Perry suggested I do a sketch of the history of celestial cartography. I was intimi-

dated by the idea. How do you do a topic like that justice? I spun my wheels for a while. The text is not exhaustive, but it traces the trends and gives the reader an appreciation of what went before *Uranometria 2000.0*."

Lovi's research was also used to draw up the final specifications of *Uranometria 2000.0* with Tirion. The specifications included the contents of the charts, layout, map projections, and the symbols to use. "We wanted to include as many useful features as we could," Lovi said. "There were conflicting criteria and tradeoffs about how much we could show without cluttering the maps."

While Lovi and Remaklus were examining historical star atlases, computer plotting of star positions became a possibility for *Uranometria 2000.0* — which changed the scope of the atlas. Wayne Warren, Jr., of the National Space Science Data Center and Carlos Jaschek of Centre de Donnees Stellaires at the Observatoire de Strasbourg were nearing the completion of a project to translate the well-known German catalogs — *Bonner Durchmusterung*, *Südliche Bonner Durchmusterung*, and *Cordoba Durchmusterung* — into computer-readable form.

Rappaport, who would be responsible for computer plotting the atlas, was already in touch with Remaklus by the time the German catalogs became available. Late in 1984 Richard Berry, editor of *ASTRONOMY*, saw samples of Rappaport's computer-plotted atlas based on the *Cape Photographic Durchmusterung* star catalog and put Rappaport in touch with Remaklus. Rappaport sent samples of his *Cape* atlas charts to Remaklus, who forwarded them to Tirion and Lovi.

Remaklus asked Rappaport to conduct feasibility studies to determine how fast a computer-plotted atlas could be completed, the size of the



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atlas, what stars to include, what catalogs were available, and the programs to use for a computer-plotted *Uranometria 2000.0*. Rappaport took into account how many stars would fit on each chart.

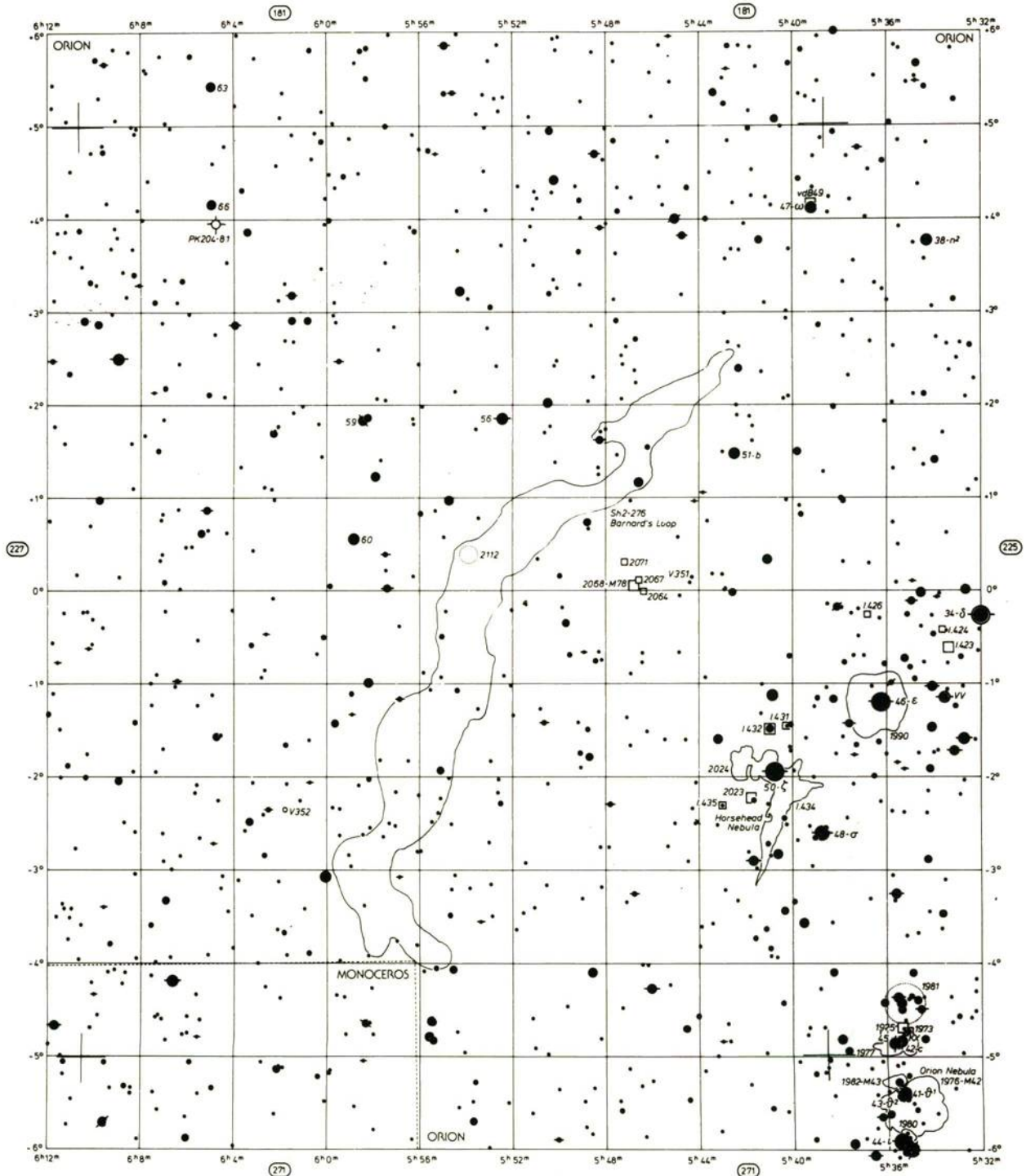
Because he had worked with the National Space Science Center on the

Cape atlas, Rappaport was able to obtain the data tapes for the three German catalogs. (He is currently cross-indexing data from the *Cordoba* catalog with the *Cape* catalog for the companion three-volume *Uranometria 2000.0 Star Catalog*.) Charles Seitz at the California Institute of Technology

provided access to large-computer facilities for the project. "It was a co-operative effort," Rappaport said.

With the computer data available, the atlas grew from 160 hand-plotted charts to 473 computer-plotted charts, which changed Tirion's role dramatically. Instead of spending five years

**Chart No. 226 from *Uranometria 2000.0* shows Barnard's Loop (center), the belt of Orion (middle right), the Horsehead Nebula near Zeta Orionis, and the Orion Nebula (lower right).**



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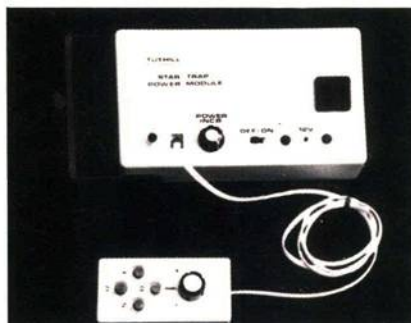
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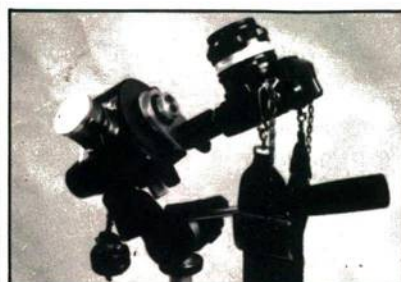
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plotting the charts, he has spent about two years labeling and adding symbols and nonstellar objects to the computer charts.

When Rappaport joined the team, Tirion had completed ten to twelve charts. By the time Tirion had finished his other projects and was ready to start on *Uranometria 2000.0*, the decision had been made to go with computer-plotted star positions. "It was lucky I spent two years on other projects," Tirion said.

With Lovi on the East Coast, Rappaport on the West Coast, and Tirion in the Netherlands, Remaklus' orchestration of the star atlas was a complicated task. Most of the discussions, planning, and decisions for the star atlas were conducted through correspondence and over the phone: Rappaport and Remaklus have never met Tirion, and Lovi met Rappaport once during the project. Tirion said communicating this way was difficult at first, but gradually he got used to it.

Once the decision was made to plot the atlas by computer, Rappaport began to assemble and check the data. Decisions needed to be made about what magnitude range the charts should cover and what corrections needed to be made in the fainter magnitudes. At this stage he was in constant phone contact with Lovi to determine the shape of the atlas. Lovi and Rappaport decided what projection and coordinate systems to use, how many charts would be needed, and how much of the sky would fit onto each chart. Lovi said he spent many hours on the phone with Rappaport, each with a calculator in front of him to work out map projections and star positions. Tirion and Rappaport spent several months working out the scale and number of charts needed for the atlas.

Rappaport first precessed all the star positions to epoch 2000.0 to show where the stars would be in the year 2000. (Much of the data was in epoch 1875.)

There was a systematic error at 9th magnitude in the *Bonner Durchmusterung* data, and the plots showed the magnitudes to be one-tenth to two-tenths fainter than they should have been, so the stars plotted at magnitude 9.2 were at least magnitude 9.5. The *Cordoba Durchmusterung* data went down to magnitude 9.5. Instead of correcting the data, Rappaport decided to use magnitude 9.2 as the cutoff point for the *Bonner Durchmusterung* data and 9.5 for the *Cordoba Durchmusterung*. *Uranometria 2000.0* plots stars of magnitude 9.5 and brighter.

To identify the stars with larger proper motions than precession would account for, Rappaport used a Luyten stellar database to identify these stars

and enter their correct positions in 2000.0 coordinates. He also compared *Uranometria 2000.0* to the *Yale Bright Star Catalogue* as a final test of positions and magnitudes and to *The True Visual Magnitude Photographic Star Atlas* to reduce the small number of errors and omissions in the German catalogs.

When Rappaport began work on the data, not all the Northern Hemisphere zones had been entered, so Rappaport added the data for those zones to the computer database for the atlas and checked the data for accuracy.

The atlas includes the fifty nearest stars, and those with magnitudes fainter than 9.5 were added.

The authors also needed to decide which nonstellar objects to include and how to get the data. Lovi suggested that the atlas contain the entire *Revised New General Catalogue*, and the catalog's authors, Jack W. Sulentic and William G. Tifft, gave Rappaport permission to use their data in the atlas. According to Lovi, *Uranometria 2000.0* is the first general purpose atlas to include the entire RNGC.

A list of 10,300 nonstellar objects, including quasars, radio sources, and x-ray sources was also drawn up; Tirion would later add those objects to the charts by hand.

When Rappaport finished the computer-plotted charts, they were sent to Tirion for completion. Tirion said he received about one hundred charts at a time. "I received just the coordinate grid in black. The stars are open circles, and the positions of RNGC objects are marked with small blue crosses." Rappaport wanted to let the computer fill in the star circles, but Tirion said that some of the symbols for the brighter stars would hide fainter stars. In the atlas stars that could be hidden by their neighbors are marked with a white ring so all the stars are clearly shown.

Tirion then examines each chart, compares it to other atlases, and makes adjustments. Every object is compared to a photographic plate. He draws the nonstellar objects, labels constellation boundaries, nonstellar objects, and stars,

and fills in the stars. All 1st-magnitude and brighter stars and other well-known stars are labeled with their common names; special symbols are drawn for multiple and variable stars, globular clusters, open clusters, planetary nebulae, selected bright diffuse and dark nebulae, galaxies, radio sources, x-ray sources, and quasars.

Tirion said it takes him approximately one day for each chart. He begins in the morning and works sometimes until 8 or 9 in the evening, depending on the amount of detail the chart contains. He is assisted by Raymond de Visser, a twelve-year-old neighbor, who wanted to help with the atlas. Tirion told Raymond he could fill in the stars and "he did it very accurately," Tirion said.

One set of about a hundred charts Tirion received contained a slight error in the grid. "It looked a little weird to me," Tirion said. After examining the charts closely, he determined that the declination lines were slightly curved. The star positions were right but the lines weren't.

Tirion could tell something was wrong with the chart just by "eye-balling" it, according to Remaklus. Tirion can't explain exactly how he eyeballs a chart. He said he can easily recognize stars, even in areas of the sky he's unfamiliar with, and when he looked at the incorrect charts, he could just see something was wrong.

Aside from this slight grid error, which has since been corrected, the project has proceeded on schedule. In April Tirion finished his work on the last charts and sent them back to Remaklus. The first volume, which covers the Northern Hemisphere, will be published late this summer; the second volume, covering the Southern Hemisphere, will be published in 1988. (Both will be available from ASTRONOMY.)

The computer database Rappaport developed for the atlas will also be used to create a three-volume *Uranometria 2000.0 Star Catalog* by Tirion, Rappaport, and Wayne Warren, Jr., which will be published late this year. Kristine R. Majdacic.

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## A Quick and Dirty Supernova Expedition

It finally happened. For five decades, since supernovae were recognized as an independent class of exploding star, astronomers have been waiting for a naked-eye supernova. On February 24, 1987, Supernova 1987A burst forth visually at 4th magnitude in the Large Magellanic Cloud.

Here it was. A supernova bright enough to see with the naked eye yet totally inaccessible from my regular observing sites in southern California. I

grabbed every available bit of information as the situation developed. My sources included IAU circulars, news reports, and the grapevine, including hallway conversations with Voyager project experimenters at the Jet Propulsion Laboratory where I work.

For years I had pondered what I would do if a bright supernova appeared out of reach deep in the Southern Hemisphere. I needed to decide if a trip to see the supernova



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| 1.32" | \$29.95  | 1.52" | \$34.50 | 1.83" | \$39.50 |
| 2.14" | \$49.50  | 2.60" | \$65.00 | 3.10" | \$89.50 |
| 4.25" | \$149.50 |       |         |       |         |

## ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

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| 1 1/4" (1.32" mirror)              | \$89.50  |
| 2" (1.83" mirror)(see photo above) | \$145.00 |

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### UHC Filter™

#### ULTRA HIGH CONTRAST

The LUMICON UHC FILTER is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. UHC stands for Ultra High Contrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 85-95%.

For optimum astronomy, use either the LUMICON DEEP-SKY Filter or the LUMICON UHC Filter



"I CAN SEE THE OWL NEBULA!" Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, "I had never seen M-97... I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment." Tom Kramer, Sayville, NY

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The LUMICON DEEP-SKY FILTER improves your view of all deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for both visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-95%.

|                                                                                                                                                  | Standard       | Premium*      |
|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------|---------------|
| 0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces                                                                                  | \$59.50        |               |
| 1 1/4" LUMICON DEEP-SKY Filter threads into most 1 1/4" eyepieces                                                                                | \$79.50        |               |
| 48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS                                    | \$119.50       |               |
| 2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography. | \$99.50        |               |
| 72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, \$8)                                                                                   | \$299.50       |               |
| 1 1/4" LUMICON UHC Filter threads into most 1 1/4" eyepieces                                                                                     | \$79.50        | \$99.50       |
| 48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces                                                                                  | \$159.50       | \$199.50      |
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| LUMICON H-BETA Line Filter (9nm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae.              | 1 1/4" \$89.50 | 48mm \$189.50 |
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\*Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.

# DEEP-SKY ASTROPHOTOGRAPHY

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LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

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Electric Vacuum Pump, Model R-10 \$280.00

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All LUMICON EASY-GUIDER™ off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms to bright guide-stars. Specify Camera and Telescope type. U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™ Full aperture. Installs in secs. Specify 2" or 1 1/4" NEWTONIAN EASY-GUIDER \$169.50 3X Relay Diagonal (see photo) \$79.50 Illuminated reticle eyepiece system \$89.50 Guider for Hasselblad \$350, Mamiya 645 \$199

CASSEGRAIN EASY-GUIDER™ For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! Superb rich field viewing, tool! CASSEGRAIN EASY-GUIDER \$225.00 Adapter for Hasselblad \$185, Mamiya 645 \$159

GIANT EASY-GUIDER™ For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. Also yields unmatched Rich-Field viewing. GIANT EASY-GUIDER \$395.00 48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE \$20) add \$99.95 Adapter for Hasselblad \$195, Mamiya 645 \$96

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1. Illuminated reticle eyepiece \$89.50 Luminon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosshairs, battery pack.
2. Cable release for long exposures \$9.95



3. LUMICON Quartz Drive Corrector \$219 Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians. Declination motor (state telescope) \$70 NEW Deluxe Digital Qtz. Drive Correc. \$298



## HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

| Film Type, 35mm                     | Exposures | Price   |
|-------------------------------------|-----------|---------|
| 2415, Ultra-fine B&W, red sens.     | 36        | \$10.95 |
| SR1600, fastest of all, color neg.  | 24        | \$12.95 |
| Konica SR200, fine grain color neg. | 12        | \$9.95  |
| 3M 1000, fastest slide film         | 20        | \$12.95 |
| Fujichrome RD100, fine grain slide  | 24        | \$12.95 |
| 5072, color slides from neg         | 36        | \$6.95  |
| D-19 B&W Developer                  | 1 gal.    | \$6.95  |

## H-ALPHA PASS FILTER



Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

| Specify Lens Size | H-Alpha | (MV)    |
|-------------------|---------|---------|
| 46, 48, 49mm      | \$35.00 | \$29.00 |
| 52, 55, 58, 62mm  | \$45.00 | \$35.00 |
| 67, 72, 77mm      | \$52.00 | \$45.00 |
| 82mm              | \$55.00 |         |

Hypered 2415 film, 36 exp. \$10.95... 3/\$29

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was worth it and if I could fit the trip within time and budget constraints.

The practical considerations were easily settled. A quick geography lesson and a study of airline schedules showed that I could make the trip at a reasonable cost. With the agreement of my very understanding wife Janet, I planned a quick trip to Acapulco, Mexico, that would allow me to see and probably photograph the supernova.

Deciding if the trip was worth the time was much more difficult. Seeing a 4th-magnitude star in an unfamiliar part of the sky only about  $3\frac{1}{2}^\circ$  above the horizon for about an hour on each of two nights under far less than ideal conditions of sky transparency would consume three of a limited number of vacation days.

Why bother? Because I knew I'd be sorry a few years from now if I passed up the chance, and because my good friend David Levy had written a book about variable stars. As an author of a book on variables, David felt he had to see the supernova. I had informally edited his book and I felt like the book's godfather, so I had to see Supernova 1987A too.

With the decision made to launch our "Moonshadow Expeditions — A.L.P.O. Comets Section Supernova Expedition (MEALPOCSSE)," astronomical considerations came into play. David and I had to match our schedules to those of the supernova, the Moon, the Sun, and the airlines. 1987A might brighten or fade soon, and it was already past the meridian and starting to set at the end of astronomical twilight in Acapulco. That situation would only grow worse while the supernova was still bright. The third week of March satisfied all our constraints.

What equipment should we bring? David decided to bring "Minerva," his 6-inch  $f/4$  RFT. With Minerva and my 10x50 binoculars we should be able to see the supernova directly, with a nebular filter, and with my spectrum eyepiece.

I wanted to get photographs but also to travel light, and the supernova's low elevation didn't warrant an elaborate effort. The high declination of the supernova was at least helpful because sidereal tracking was less critical. My tripod-mounted, homebuilt STELAS Mark IV could drive a camera. I brought a 50mm  $f/1.4$  lens, an 8x50 finder I had modified for visual and photographic use (it is a 50mm  $f/5$  telescope), and a 300mm  $f/5.6$  catadioptric lens because aperture rather than focal ratio is the key to photographing stars. A set of filters ranging from a yellowish Minus Violet to orange and red would be helpful near the horizon, and diffraction gratings

would allow me to photograph the spectrum.

Three days before we left, Charlie Oostdyk joined MEALPOCSSE, adding his 6-inch RFT and camera to our instrument collection. Thus equipped, we winged our way south. Elizabeth Taylor and George Hamilton were on our flight. David wondered if they were going to see the supernova too.

We found that Acapulco's weather was not as clear as it was supposed to be: high cirrus clouds were everywhere. On the way from the airport we spotted a potential observing site and returned there that evening.

There we were. On an overlook along a busy road with headlights blazing by, we stood looking through cirrus and scudding coastal cumulus clouds, searching an unfamiliar part of the sky for a star  $3\frac{1}{2}^\circ$  above the horizon and  $10^\circ$  from any familiar or unobscured star-hopping landmarks.

Sweeping the horizon with binoculars, I found two stars at about the right altitude and azimuth. Pointing Charlie's 6-inch there I saw the stars and a faint blob down and to the right. The nebular filter dimmed the sky but not the blob, so I knew I had found the Tarantula Nebula in the Large Magellanic Cloud. The brighter, closer star to it was the supernova, as we confirmed at the hotel later with star charts and photos. When we returned to the hotel, we were happy enough to pay our driver Vicente's exorbitant rate.

Our hotel's desk manager turned out to be an astronomy enthusiast. He suggested a trip to the mountains, so the next afternoon we piled into a small taxi and headed inland with him as a guide. We hoped to at least avoid the coastal cumulus clouds, which we did. Even the cirrus clouds were thinning, and with local help in El Rincon we found a protected site with a good southern view.

As the sky darkened, the first night's celestial landmarks and many other star-hopping jump sites appeared. The supernova was about  $2^\circ$  below a knob of hill but we thought it would move out from behind the hill. In ten minutes we could see that the supernova's diurnal motion would keep it below the knob, paralleling the sinking hill slope.

We beat a hasty retreat to an alternate site south of El Ocotito. It was private property, but we found no one to ask for permission for a visit, so in the heat of the moment we decided to trespass. We passed through a barbed wire gate, up a road, across a field, climbed through a barbed wire fence, and ran up "Mount Illegal," all by penlight!

From the top of a room-size boulder we saw our defeat from another hill.

Making the best of a bad situation and good skies, we spent an hour showing our driver and guide the Eta Carinae Nebula, the open cluster NGC-3532, Gamma Velorum, Zeta Puppis, M-42, and Sirius.

Our last day dawned clear. Having come this distance without a satisfactory view and the weather finally matching long-term averages, we called home and arranged to stay one more night after confirming we could catch a flight home that would allow me to keep a speaking engagement scheduled months ago.

Patient Vicente, who had proved his good humor with us the first night, agreed to a more reasonable price this time and returned us to our Puerto Marques overlook. The weather looked good; we readied our cameras and telescopes. It felt like the period just before an eclipse.

As the sky darkened we used our previous nights' celestial and terrestrial landmarks to quickly locate the supernova and confirm our first night's fleeting glimpses. Now my advance planning paid off. We spent a frantic seventy-five minutes estimating the supernova's magnitude, noting its red color (even compared to other stars as near the horizon), checking its spectrum visually, photographing it directly and with a diffraction grating, studying the Tarantula Nebula, and quietly waiting out the passing clouds that had returned to harass us.

Finally 1987A was no longer visible. We packed up as the locals who stopped at the overlook to party continued to down their whiskey.

The next morning after an ocean swim and brunch we returned to our hotel to find our transport back to the airport waiting. The plane was late leaving Acapulco, which meant I was sure to be late for my talk to the Ventura County Astronomical Society on solar observing and eclipses.

After an amazingly quick retrieval of my suitcase and a fast trip through customs and immigration, I met my family and then contacted the VCAS to tell them I was on the way. (My thoughtful wife had already warned them that my plane was late.) I organized my lecture slides during the ride to the meeting, only partially dumping them twice. The talk was well-received. I gave them a firsthand account of the supernova and its implications on solar studies.

Was our supernova expedition a success? Yes. We learned more astronomy, saw Supernova 1987A, were impressed by the southern sky, and have memories to keep and many fun stories to tell. How could it have been otherwise?

Stephen Edberg  
La Canada, CA



Sooner or later, all of the secrets of the heavens are revealed in the only book club of its kind, the

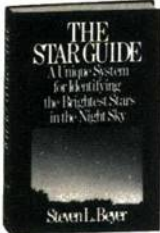
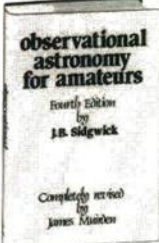
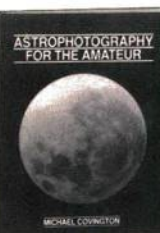
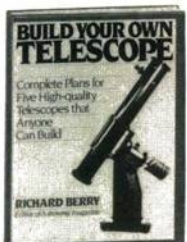
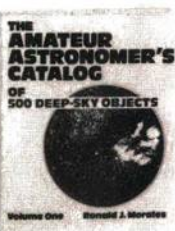
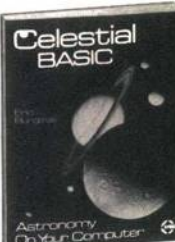
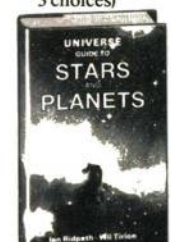
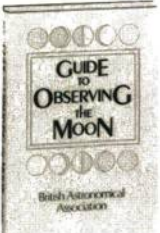
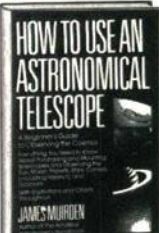
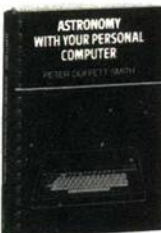
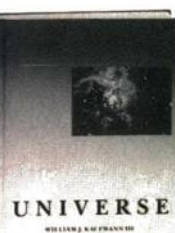
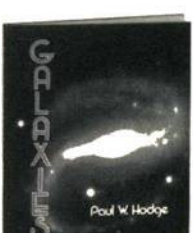
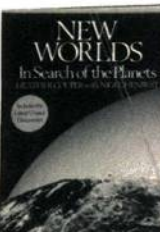
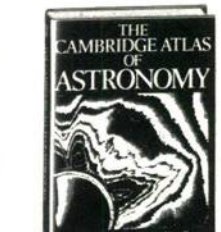
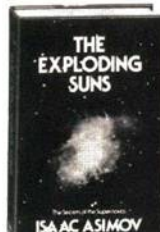
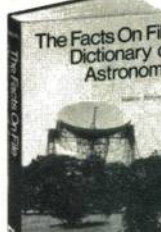
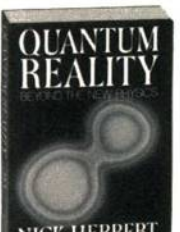
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# ASTRONOMY

## In Focus

### Dark Adaptation Can't Be Accelerated

Sir / Techniques for accelerating dark adaptation would be useful to astronomers, as suggested by Vic Stryker (In Focus, May 1987). Unfortunately, the physiology of the eye offers little hope for speeding up the process.

In the light-adapted retina the concentration of rhodopsin, the pigment sensitive to red light, is low. Rhodopsin must be enzymatically regenerated in the dark: this relatively slow process is the rate-limiting factor in dark adaptation. Eye blinking cannot influence this biochemical conversion. The frequently quoted ten to forty minutes for dark adaptation are averages for low to moderate adaptation; maximal dark adaptation can take ten to eighteen hours.

The influence of rhodopsin is tremendous: changes in the concentration of this photochemical from light to dark conditions can increase light sensitivity in the retina up to a million times. Pupil size and neural-adaptive factors are the only other known influences on the eye's sensitivity to light, but the effects of these are four or more orders of magnitude smaller than those of rhodopsin.

The best advice for maximizing your sensitivity to dim light is to consistently avoid all light for as long as possible before observing. Light adaptation is much faster than dark adaptation, so even a brief exposure to light must be avoided.

Sufficient time must be allowed for continued dark adaptation during the observing period. Sensitivity increases 10-fold in the first minute, 6,000-fold in twenty minutes, and 25,000-fold in forty minutes of dark adaptation. So a faint object that may be overlooked in an early part of the observation period may be readily observed later.

Jerry Tremblay, M.D.  
Medical University of South Carolina  
Charleston, SC

### In-Home Observing Tips

Sir / Patrick Drigans' letter (In Focus, May 1987) spurred us to report on our observations from inside the house, which allows us more opportunities to observe. Most people probably have windows made of glass well below the quality Mr. Drigans recommends. But we also found that the temperature difference between the outside and the inside of the window distorted the images of what we were observing.

Our solution was to set up our telescope in an open window and put a box fan in another open window of the same room, so the fan pulls the outside air through the window in front of the telescope and pushes air out through the other window.

Both the telescope and the room cool to about the outside temperature, and the images are reasonably good. We've followed five of Saturn's moons around the planet, the larger surface features of Mars, many changing surface features of Jupiter, and Jupiter's Galilean satellites. We've traced asteroids and have seen dozens of nebulae, galaxies, and globular clusters.

Our observing room does get cold. Our window observing has, however, permitted us to log many more hours during the week than we could get in any other way.

David and Carroll David Rawn  
Maplewood, New Jersey

### Challenging Venus

Sir / I regularly view Venus with my 8-inch SCT during the day. Although the planet is featureless, it is best seen during daylight because the brightness of the planet isn't as overpowering as it is in full darkness. I have seen the planet in all its phases, though you must be careful about observing it when it approaches conjunction with the Sun!

The most pleasurable aspect of observing Venus during the day is not

studying the planet but locating it. At night it's too easy!

My next target is Mercury. Can it be found in broad daylight?

Jack Simison  
Nepean, Ontario, Canada

— *Mercury, Venus, Mars, Jupiter, Saturn, and most bright stars are visible in the daytime sky with telescopic aid, and Venus, Mars, and Jupiter are visible to the naked eye if the sky is clear and free of haze.*

### The Enormity of Betelgeuse

Sir / I enjoyed "Betelgeuse" by David H. Levy and Peter Jedicke (April 1987). According to the article, this star is about 1.5 billion kilometers in diameter. That would be about 940 million miles. If our Sun were the size of Betelgeuse, it would reach out beyond Jupiter. That is enormous!

I would enjoy seeing other articles about stars like Canopus, Arcturus, Vega, and Rigel.

Theodore Schendel  
Bristol, WI

### Pennsylvania's Southern Sky

Sir / Every northern observer who appreciates a view of M-13 through 7x50 binoculars must also wonder what Omega Centauri would look like in binoculars. Most of us associate Omega Centauri with the "deep South," and though someone reported seeing it from Tennessee at 39° north latitude, I never hoped to see it from Pennsylvania.

A friend of mine recalled drawing Zeta Centauri along with Comet Halley during an observing session last year from 40°15' north latitude. He pointed to Omega Centauri's position on the star chart we were using and, as I stared at the chart in disbelief, he grabbed his binoculars and aimed them at a point below Corvus. Before I



could say it was impossible, he found Omega Centauri! We watched for about half an hour. It was low enough that even a 13-inch telescope couldn't resolve it, but its size amazed us and the binocular view was great.

Jonathan E. Dolby  
Williamsburg, PA

### The Age of Quasar Light

Sir / In "Star Hopping to a Quasar" by John Mood (Gazer's Gazette, April 1987), the author stated that the photons from quasar 3C 273 are older than any rocks on Earth. This isn't true. Though the quasar is about 3 billion light-years distant, most continents exhibit rocks between 3.2 billion and 3.5 billion years old, with more notable samples in Greenland and Australia where determined ages are approaching 4 billion years.

Gary W. Finiol  
Idaho Springs, CO

### What Time Is It on Apple Computers?

Sir / I am the author of "What Time Is It?" (Equipment Atlas, February 1987), and I wanted to point out that some microcomputers, especially the Apple II and Commodore 64, can only recognize the first two characters of a variable name. This means that LAM is treated the same as LAST and JD0 the same as JD, which obviously changes the program for computing sidereal time and causes errors.

If you have this problem, change LAM to LQ, TO to ZZ (Apple computers don't like the variable TO), and JD0 to J0 in the program. Make the appropriate changes on lines 420, 430, 470, 480, 490, 500, 510, 520, 530, 560, 600, and 610.

When you make corrections on the program, you'll find working on an ASCII text file in your word processor easier than using the line editor in the program itself.

Richard C. Walter, Jr.  
Lancaster, PA

### Looking Forward to 2061

Sir / Halley's Comet may never again command the awe and anticipation of millions of observers as it did last year. Perhaps in 2061 only a handful of comet specialists will even think of looking for Halley's Comet.

The 1910 survivors handed down a large number of favorable reports of the comet to the present generation. But probably no more than 2 percent of the population in areas with observatories actually saw the comet in 1985/86; the average is probably less than 1 percent worldwide. So the fate of Halley's Comet rests with the few

tenths of a percent of the world's population who will pass on favorable impressions of their experiences.

However, the prospects for Northern Hemisphere visibility of Halley's Comet in 2061 look considerably better. Excellent morning visibility in July for mid-northern latitudes should continue through July 25, only two days before perihelion. Good evening visibility seems likely as soon after perihelion as August 9. Three or four days after perihelion the tail may well be seen sweeping upward from the northwestern horizon in evening and passing under the pole moving "side-ways," reaching the northeast by morning twilight. The Full Moon will dim but hopefully not destroy the view.

A stunning ten-day long spectacle will be available at a site where the Full Moon cannot interfere — the dark backside of the Moon itself. The jet

jaunts to Australia may well be replaced by moonship flights to the Halley Lunar Base at selenographic coordinates 180 degrees by about 85 degrees north. There Halley will do a stately perihelion dance just above the northwestern to northeastern portion of the dark lunar horizon, its tail scraping past the bowl of the Big Dipper, continuously visible until the end of the long lunar night. I wish I were going!

Steve Dodson  
Astrosphere Manager  
Science North  
Sudbury, Ontario, Canada

### Oops!

The stars in May's Backyard Astronomer star map on page 105 were printed upside-down relative to the grid and deep-sky objects. ASTRONOMY regrets the error.

## Behind the Scenes

### Summer Observing Ahead

Now that warm weather has returned, many ASTRONOMY readers have been spending more time under the stars. Among those readers are many "new" stargazers, those for whom Comet Halley awakened (or reawakened) a latent interest in astronomy. If you are one of them, I hope you enjoy getting acquainted with the stars and are beginning to feel comfortable under the night sky.

I've become uncomfortably aware that many of the "Comet Halley Specials" purchased last year or the year before are now in use. Sad to say, some of these telescopes are not up to the standards of amateur astronomy. If you're feeling discouraged with one of these telescopes, you have a right to be.

To those who need a little encouragement, think back a bit to what got you interested in astronomy in the first place. Was it the sparkling stars, the immense spans of space and time, or the mind-boggling thought of great galaxies spinning through the void? Go back to those ideas again. Let them recharge your imagination and give you new energy.

On a happier note, this issue delves into the exciting world of modern professional astronomy with Robert Reeves' account of his visit to McDonald Observatory. Anyone who's been reading ASTRONOMY

for a couple years has surely noticed the surge of computer-generated electronic imagery appearing in our pages. This is a tremendously exciting development because it is making the current generation of ground-based telescopes ever more powerful.

At the amateur level, backyard astronomers have discovered that superb new films, which have become available only in the last few years, are making astrophotography easier and more rewarding than ever before, as Simon Tsang's beautiful images of the southern Milky Way (Photography in Astronomy) testify. And you don't need a telescope for astrophotography. Wally Pursell's simple hand-cranked camera platform (Equipment Atlas) can get you started with constellation photography. If ever there was a good time to get started in astrophotography, this is it.

With all the high-tech talk and fast films, let's not forget, though, that there's still nothing that beats the thrill of gazing up at a star-filled sky.

Sincerely,  


Richard Berry  
Editor-in-Chief



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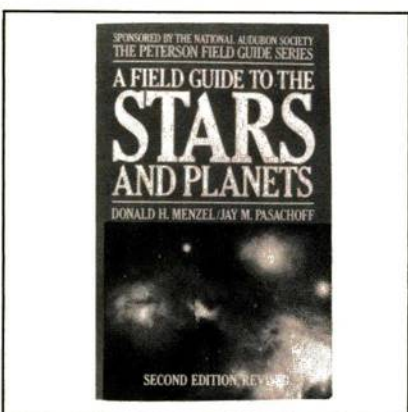
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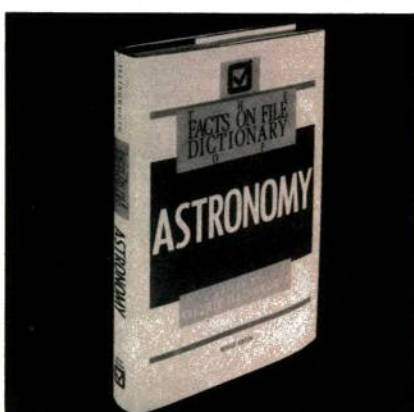
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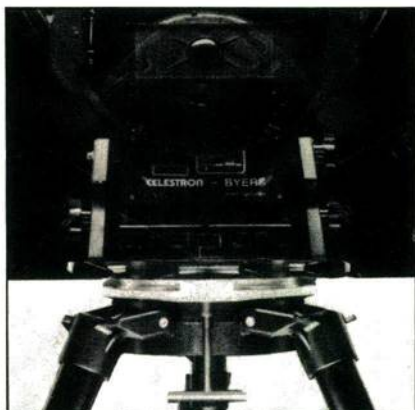


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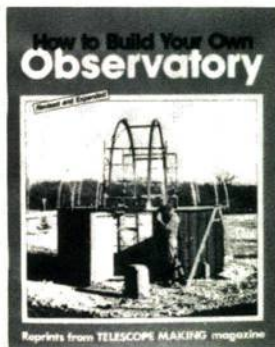
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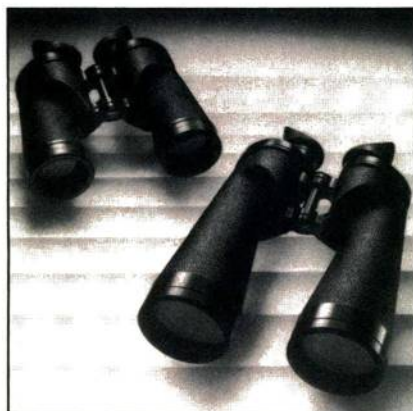
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# ASTRONOMY

## Reviews

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### Thursday's Universe

Marcia Bartusiak  
306 pages, cloth, \$19.95  
ISBN 0-8129-1202-0  
Times Books (1986)

In books on popular astronomy published thirty years ago or more, the universe often sounds curiously muted, as if astronomers back then had only a few murky colors to work with. The old universe was a quiet place, expanding to be sure, but mostly filled with decent, normal stars stolidly going about the business of fusing H into He. But in the past two decades so many weird objects have been discovered — new kinds of objects — that the old views of the universe look, well, sort of dowdy in hindsight.

Reporting from today's astrophysical frontier, Marcia Bartusiak's book is certainly not dull or dowdy. Written at the level of *Discover* or the late, lamented *Science* '86, it is comprehensible to anyone interested in the subject. This doesn't mean the ideas it covers are easy to grasp — many are not. But if the astronomy articles in *Scientific American* tend to lose you by the third paragraph, you'll enjoy this book a lot.

Each of the eleven chapters centers on a topic of prime interest to astrophysicists today. Few of these chapters present a totally coherent picture of current thinking, but this is not the author's fault. Most questions she deals with are not settled (they wouldn't interest researchers if they were), and so the confusion she reports on is a clear sign that astrophysics is in a healthy state.

The book begins by examining how stars form out of the interstellar medium — a much richer environment than anyone suspected in the 1950s. The centerpiece is the work done by Charles Lada on M-17, the Omega Nebula in Sagittarius, and its later generalization to all diffuse nebulae by Bruce Elmegreen. Elmegreen and Lada show that star formation does not happen all over a dense cloud of molecules and dust (as was

thought) but in a sequential and remarkably systematic way. Beginning at one edge of a cloud when something triggers a few large stars to form and then explode as supernovae, a chain reaction of shock fronts progressively nibbles into the cloud; each new round of star formation is driven by the death throes of the previous one. Elmegreen and Lada's conclusion is important: once star formation is initiated, it basically runs forever, and the only thing that can shut down a galaxy's star factories is a lack of raw material.

Next, white dwarf stars open up a discussion of highly condensed objects. Though they had been observed since 1862 when Alvan G. Clark spotted Sirius B ("the Pup"), white dwarfs weren't named and their nature understood until 1926. Even then many astronomers could hardly believe what their equations told them about a white dwarf's density: a white dwarf is so compressed that a matchbox would contain a ton's worth of stuff. This extreme density seemed to be the end of the line for stars. But in the 1930s the theoretical astrophysicist Subrahmanyan Chandrasekhar wondered what would happen to a star that was more massive than any white dwarf yet seen. The answer was a vastly more compressed object known today as a neutron star. "Its density," says astronomer Jonathan Grindlay, "is roughly equal to packing all the world's automobiles into a thimble." This kind of density was flatly unbelievable to most astronomers in the 1930s, and therefore the objects remained a theoretical construct buried in the yellowing pages of a few journal articles. And that remained the case — until 1967.

In that year, graduate student Jocelyn Bell spotted the radio signature of the first pulsar on miles of output from a chart recorder connected to an English radio telescope. Less than a year later, after all sorts of wacky hypotheses (including signals from an extraterrestrial civilization) had been ruled out, the consensus of astronomers was that a neutron star had at last been found. Once neutron stars

were out of the bag, no one was going to gamble a future Nobel Prize by ignoring "airy-fairy" theoretical ideas. Soon every weird concoction in the literature was studiously searched for and, remarkably often, found. One such idea was the black hole.

Though by definition black holes are invisible, they produce visible effects on the space-time in their vicinity and emit gravity waves. Gravity waves have not yet been detected reliably, though foreseeable instrument improvements offer hope for a detection in the near future. In any case, it is clear that a couple of binary star systems — Cygnus X-1 and SS 433 for example — incorporate very massive, invisible objects. Barring something totally unknown, a black hole is the simplest explanation for the invisible object.

Bartusiak takes the reader for an exciting tour of the laboratories where black holes were "invented," theorized about, and are now searched for. Years ago John A. Wheeler concocted the name black hole in a straightforward attempt to bring the subject into the mainstream of astrophysics. "Physicists," he says, "are like patients in a doctor's office. They only really believe they know what their problem is when they give it a name." We then visit with gravity expert Kip Thorne, who wants to see the gravity waves emitted when two black holes collide: "That's my favorite event in terms of the physics to be learned. . . . If I had to lay bets on how we'll finally get 100 percent proof that black holes exist, it's that event."

Bartusiak also explored a rich field of cosmological questions. Will the expand-

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ing universe expand forever? What might stop it? How large is "now"? One outstanding conundrum is why the universe appears so flat: it looks as if the universe is poised exactly on the line between being open (expansion will continue forever) and being closed (it eventually stops).

The problem is complicated by "dark matter." Studies of the motions of galaxies in clusters and of stars within galaxies have long shown that something unseen is controlling the movements of the visible material. This unknown dark matter appears to outweigh the visible matter by a factor of ten to one hundred times. (Think of it, all the visible stuff in the universe is only 1 percent to 10 percent of what's really there!) Identifying and describing this dark matter is one of the most important and challenging tasks facing astrophysicists today. But what is it? No one knows, though a veritable avalanche of papers have proposed solutions, many that include new elementary particles with carefully contrived properties. To date, none of the "paper particles" has been found, and the mystery of the dark matter remains unsolved. But, as Bartusiak notes, by any measure we're in for a long, big universe.

As I read chapters on how galaxies formed out of the Big Bang, what the large-scale structure of space-time is, what happened *before* the Bang, and so on, I couldn't help wondering why astronomers earlier in this century didn't stumble onto at least some of these problems. In many cases all the essential pieces of evidence lay right in front of them. I think, in the end, two things conspired against them. First, their writings make it clear they just didn't believe "strange things" existed. You could say they had invested too heavily in a normal universe. This is why, for example, the idea of black holes escaped serious examination for so long.

Second, yesteryear's astronomers were working almost exclusively in the optical region of the spectrum. One reason the present age will be remembered as a golden era for astronomy is the opening up to view of the entire electromagnetic spectrum. Until recently, nonoptical astronomy's role was to supplement and confirm the results of optical work, which was expected to point the way. These days the process is usually turned around. Today's researcher may use an optical telescope on one object, a radio scope on another, and an x-ray satellite on a third — or perhaps all three instruments on the same object. Astronomers now have the freedom to pick the wavelength that best attacks the problem. *That* is a big change from yesteryear.

Bartusiak's interviews strongly convey that astrophysicists are relatively ordinary people working on extraordinary subjects. Scientifically knowledgeable and asking the right questions, she has convinced normally reticent researchers to open up

and tell more about their work than practically any other journalist I've read. (Tim Ferris, in *The Red Limit*, is another.) Bartusiak fills in their backgrounds and brings her people to life on the page by noting individual personalities and ways of thought. She's quite good at it — we hear how Alan Guth's inflationary model for the early universe was cooked up late one night and now sits on four sheets of paper, covered in small, precise handwriting and neatly tucked away in a cherry-red binder. Somehow a theory that wraps up so many cosmological loose ends *ought* to be as tidily contained as this.

On the other hand, now and then the story can read uncomfortably like *Time* Magazine. Although the narrative never sinks to a "Wowee-Zowee" level, vivid details don't always advance the story and on occasion the requisite quotation from a researcher (an overworked technique of journalism) merely restates what we've just been told without adding much.

Another problem concerns numbers. Since the intended reader is nonmathematical, the author and astronomers have worked hard to present their concepts in verbal analogies. These are generally quite successful, but reading a relentless series of them can feel as insubstantial as biting into cotton candy. Very much to my surprise, for I'm not any kind of a physicist, I found myself looking for a few more numbers and perhaps an equation or two.

My biggest complaint, however, is that the book suffers from a lack of illustration. The only pictures are those that face the chapter openings. While each relates to the material in the chapter, it does not adequately supplement the argument within. Ultimately the pictures serve only as symbolic decoration. I'm not sure who's at fault here. The author might have felt that words were the important medium and left the illustrations up to the book designer. If so, the designer apparently felt one incomprehensible "scientific picture" per chapter was plenty! Whatever the case, many models that are talked about at length could have been easily explained with a picture or a diagram.

But despite my grumbles, this is unquestionably the book to have if you want to catch up on what's been happening in astronomy the last few years. It is solid, entertaining, and informative. You'll like it.

And what about the book's title? Why *Thursday's* universe? You've forgotten your nursery rhymes. Thursday's child — like our expanding universe — is the one who has far to go. *Robert Burnham.*

#### **Images of Comet Halley**

20 slides with explanatory booklet, no price given  
European Southern Observatory (1986)

This set contains twenty natural and false-color slides of Halley's Comet, made

by astronomers at the European Southern Observatory in La Silla, Chile.

#### **X-Ray Emission of Auroral Electrons and Magnetospheric Dynamics**

Leonid L. Lazutin  
220 pages, cloth, \$79  
ISBN 3-540-15335-7  
Springer-Verlag (1986)

*X-Ray Emission* is a technical monograph exploring balloon studies of auroral x-rays made in the Soviet Union.

#### **Build Your Own Satellite Dish Antenna**

Gordon L. Williams  
44 pages, paper, \$12  
Power Gain Systems (1986)  
[publisher's address: P.O. Box 2955, West Monroe, LA 71294]

Williams' book is a how-to manual for constructing an operating satellite dish. The dish's primary purpose is to receive television signals, but the author points out that such an antenna could be used for backyard radio astronomy as well.

#### **Chart of the Heavens**

Wil Tirion  
27" by 19" chart with mylar overlay, 3.50 British pounds  
British Astronomical Association (1986)

This two-color (blue and black) wall chart shows stars as faint as magnitude 5.25 and several dozen deep-sky objects. At the top are two circular plots that show the sky centered on the north and south celestial poles; below them is an equatorial projection showing a strip of sky between  $-40^\circ$  and  $+40^\circ$  declination.

#### **Astronomical Calendar 1987**

Guy Ottewill  
65 pages, paper, \$12  
ISBN 0-934546-16-9  
Furman University (1986)  
[publisher's address: Greenville, SC 29613]

The seventeenth edition of this annual compilation features information about the night sky during each month and observing details about the planets, meteor showers, comets, asteroids, and eclipses.

#### **Progress in Solar Physics**

C. de Jager and Z. Svestka, eds.  
619 pages, cloth, \$99.50  
ISBN 90-277-2180-7  
D. Reidel (1986)

*Solar Physics*, an eighteen-year-old international journal of research on the Sun, recently published its hundredth



volume. To celebrate, D. Reidel issued it in book form: the result contains many technical papers about solar research.

### The Galaxy and the Solar System

Roman Smoluchowski, John N. Bahcall, and Mildred S. Matthews, eds.  
483 pages, cloth, \$29.95  
ISBN 0-8165-0982-4  
University of Arizona (1986)

This semitechnical volume, written at the advanced undergraduate and graduate level, offers an analysis of the relationship between the Galaxy and our solar system. The book's twenty-two chapters address questions like: "Does the Sun have a companion star?" and "How is the solar system affected by the Galaxy surrounding it?"

### The Amateur Radio Astronomer's Handbook

John Potter Shields  
104 pages, paper, \$19.95  
ISBN 0-517-55810-6  
Crown Publishers (1987)

Written for amateur astronomers with a moderate dose of electronics know-how, the *Amateur Radio Astronomer's Handbook* provides advice on building and

maintaining a radio dish, detecting meteors and electromagnetic disturbances from the Sun, and listening for radio-frequency emissions from stars.

### The Use of Supercomputers in Stellar Dynamics

P. Hut and S. McMillan, eds.  
240 pages, cloth, \$28.90  
ISBN 3-540-17196-7  
Springer-Verlag (1986)

These are the proceedings from a workshop on the use of supercomputers in stellar dynamics, held in 1986 at the Institute for Advanced Study in Princeton, New Jersey. Among the papers are "Dynamical Evolution of Globular Clusters" by Lyman Spitzer, Jr., "On Toolboxes and Telescopes" by Piet Hut and Gerald Sussman, and "Modelling Stellar Dynamical Systems on the CRAY-1S and the CDC Cyber 205" by R. A. James.

### Exploration of the Universe, 5th edition

George O. Abell, David Morrison, and Sidney Wolff  
755 pages, cloth, \$42.75  
Saunders College Publishing (1987)

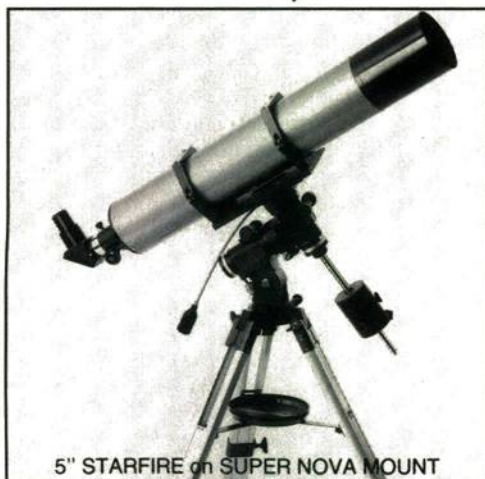
Anyone with more than a casual interest in astronomy should have at least one

good textbook. Observing guides, star atlases, and popularizations all have their places in an astronomy library, but every bookshelf, however short, has a big hole if it doesn't feature a textbook too. The reason is simple: no other kind of book can pull the whole field of astronomy together for you quite as well as a textbook can.

As an amateur astronomer you are faced with trying to meld two rather separate astronomies — the backyard kind you pursue yourself and the science as a whole. The former is easy and enjoyable, but the latter can appear forbiddingly difficult. Admittedly, astronomy conducted at the research level is difficult to understand without professional training. But if your knowledge of astronomy encompasses only what your telescope can show, you're missing a lot of what is easily within your grasp.

George Abell wrote the first edition of *Exploration of the Universe* in 1964. When I used it in college during the late 1960s, it was already out of date in several respects. This wasn't Abell's fault; astronomy was just moving along awfully fast. Nonetheless, you can't imagine how exhilarating I found watching my textbook visibly grow dated in front of me — nothing could have imparted a sense of astronomy's dynamism more strongly. The second through fourth editions soon fol-

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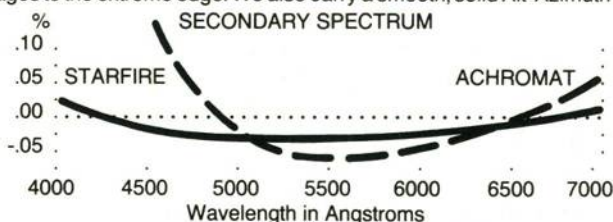
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lowed, as Abell revised the book to keep pace with the changes in the field.

The fifth edition of *Exploration*, the first since George Abell's death in 1983, is a revision by two of today's most knowledgeable astronomers that brings this classic work up to date. David Morrison, a planetary scientist at the University of Hawaii, has been heavily involved with the Viking and Voyager missions and worked primarily on the solar system half of the book. Sidney Wolff is at Kitt Peak National Observatory in Tucson, and, because her field of research is galactic and extragalactic problems, she revised the "deep-space" sections.

The overall arrangement of the book is the same as in previous editions. A historical overview comes first, then the solar system, followed by stars, nebulae, and galaxies. But within that framework, topics have been reshuffled where knowledge has been gained or where the exposition has needed improvement — star clusters now follow the section on stellar evolution, for instance. The book is remarkably up to date: it includes preliminary data and photos from the Voyager encounter with Uranus as well as the multiprobe missions to Comet Halley.

The section on the solar system is the most comprehensive I've seen since William Hartmann's *Moons and Planets*. Although *Exploration* treats each planet separately, the authors weave together common themes that snap the picture of the entire solar system into focus. Likewise, the survey of stellar and galactic structure and cosmology is superbly presented. The relationship of molecular clouds to star formation is clearly laid out as is the evolution of these stars on the color-magnitude diagram. What do we know of the large-scale structure of the universe? The story is told in a way that blends personalities and techniques into a portrayal of striking immediacy.

Of course, the very word "textbook" may evoke those warm, droning school days when it seemed as if summer vacation would never arrive. Textbooks usually do avoid too colorful a style because neither reader nor author can sustain that pace for many hundreds of pages. Nonetheless, and duly noting that tastes differ widely, I don't find *Exploration* the slightest bit dull. It is clearly written, worked-out examples are given for nearly every formula, and answers are provided for many of the exercises. This is an excellent book for learning the rudiments of astronomical science, to the extent one can learn them on one's own.

Quality of writing is one thing, but it doesn't entirely explain why my old copy of Abell has sat among my essential reference books for the last twenty years. Its usefulness is explained by its treatment of mathematics: almost alone among textbooks, *Exploration* neither banishes mathematics nor wallows in it. Nearly all textbooks aimed at liberal arts majors stick

to a basic, descriptive approach. At the other end, texts aimed at science students familiar with calculus and physics lower the mathematical boom early and never let up. By providing more math than the "astronomy for poets" textbooks but avoiding the rigor that science majors need, Abell skillfully steered a pedagogical path between the two extremes. Fortunately, the new edition maintains the tradition.

Math — why do I harp on something most backyard astronomers take pains to avoid? Believe me, the day eventually comes when using a little math increases the fun of astronomy significantly. While JPL is never going to call on me for help in planning deep-space missions, I can still enjoy working out for myself how long it would take a space probe to coast out to Pluto on a minimum energy trajectory. (The answer, by the way, is depressingly long: 46-1/2 years to reach 40 AU.) I get the same joy from using the spectral class of a star and its absolute magnitude to derive its size.

Anyone who wants a purely descriptive approach can easily skip the more detailed sections, which are printed in lighter type. (In fact, years ago Abell published several condensed versions of *Exploration* that omitted nearly all the numbers.) But I really wonder how many backyard astronomers would be completely satisfied with that.

Whatever your level of interest, I recommend the new *Exploration of the Universe*. It's undeniably pricey, but you'll get solid value for your money. *Robert Burnham*.

### **The Physics of Accretion onto Compact Objects**

K. O. Mason, M. G. Watson, and N. E. White, eds.  
421 pages, cloth, \$40.60  
ISBN 3-540-17195-9  
Springer-Verlag (1986)

*Accretion onto Compact Objects* is a highly technical proceedings volume from a 1986 conference on the subject held in Tenerife, Spain.

### **Masks of the Universe**

Edward Harrison  
306 pages, cloth, \$18.95  
ISBN 0-02-948780-3  
Macmillan (1985)

In his preface Edward Harrison states: "the universes that we create and in which we live determine the meaning and purpose of life." His book examines the history of these diverse universes created by mankind and describes each as a mask placed on the face of the real universe.

Central to Harrison's theme is that these masks, developed by both primitive and advanced cultures, are models organizing

physical reality into a comprehensible form that gives meaning and purpose to life. Each mask or model of the universe — from primitive man's animistic beliefs to today's theories of quantum mechanics — constitutes the valid knowledge of a particular society and determines what is perceived and believed by that society. Every mask, then, is a quest for the ultimate universe, and it remains until it is replaced by another that better reflects cultural and scientific ideologies.

### **Space Dynamics and Celestial Mechanics**

K. B. Bhatnagar, ed.  
458 pages, cloth, \$99  
ISBN 90-277-2311-7  
D. Reidel (1986)

*Space Dynamics and Celestial Mechanics* is the result of a series of lectures delivered at a November 1985 international workshop on these subjects in New Delhi, India. The book reviews the current state of the art in these fields. Included are such topics as "Qualitative Study of the N-Body Problem," "Stability of Motions of Asteroids," "Numerical Experiments on the Formation of Tails and Bridges in Galaxies," and "Satellite Attitude Acquisition by a Momentum Bias System."

### **Hydrogen Deficient Stars and Related Objects**

Kurt Hunger, Detlef Schonberger, and N. Kameswara Rao, eds.  
506 pages, cloth, \$89  
ISBN 90-277-2326-5  
D. Reidel (1986)

Hydrogen deficiency is a widespread phenomenon occurring in a large number of stellar and nonstellar objects. Although the first helium star (a star containing more helium than hydrogen in its outer layers) was discovered in 1942, the first scientific meeting on this rather esoteric subject was held only recently. This volume contains the proceedings of that meeting, the 87th Colloquium of the International Astronomical Union, held in November 1985 at Mysore, India. Topics include hot extreme-helium stars, cool hydrogen-deficient stars, hydrogen-deficient binaries, intermediate helium stars, and IRAS results.

### **Voyager at Uranus**

Sherwood Harrington, ed.  
15 slides with explanatory booklet, \$14.95  
Astronomical Society of the Pacific (1986)

Highlights of this slide set include a color composite showing Uranus, Miranda, and the Uranian rings, cloud motion across the planet's surface, close-ups of the major moons, and surface features of Miranda.



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# Clouds of the Twilight

by David McConnell

The Sun has just set on another long midsummer's day. As twilight gradually deepens you happen to glance up at the sky and notice some unusual and beautiful clouds vaguely reminiscent of cirrus clouds but with a much more intricate, bandlike structure. You have never seen such brightly lit clouds this late in twilight before and wonder what they can possibly be.

These mysterious clouds of the twilight are just one of several different varieties of noctilucent clouds. They occur high in Earth's atmosphere during the summer months and can be seen from high latitude locations. But what causes noctilucent clouds, what are their characteristics, and under what conditions are they visible? Scientists do not yet have definitive answers to all these questions, but they have learned a great deal about this interesting atmospheric phenomenon.

Noctilucent clouds — NLCs for short — are tenuous clouds that appear brilliant and silver-colored against the twilight sky. Their name derives from the German *Leuchtende Nachtwolken*, which means "luminous night clouds." This is a partial misnomer, however, because NLCs are clouds exclusively of the twilight and are not visible at night. They are illuminated by sunlight when the Sun is between  $6^\circ$  and  $16^\circ$  below the horizon.

In recent years scientists have made substantial progress in understanding the process of noctilucent cloud formation. Current theories propose that water vapor freezes onto tiny particles — a debate continues about what the particles actually are — in the coldest regions of Earth's atmosphere.

Noctilucent clouds are located about fifty miles above the Earth's surface. They have no connection with normal weather clouds, which form in the troposphere, the portion of the atmosphere within ten miles of the Earth's surface. Noctilucent clouds are found much higher up — not in the next layer, the stratosphere, but at the top of the mesosphere, the layer above that. More precisely, NLCs lie at the meso-

pause, which forms the boundary between the mesosphere and the highest atmospheric layer, the thermosphere. At a height of about fifty miles, NLCs are some ten times the average height of cirrus clouds, the highest tropospheric clouds and the ones that most resemble NLCs. In comparison, the lowest aurorae occur at around fifty-five to sixty-five miles.

The mesosphere, like the troposphere, is a region where temperature decreases with increasing height. The decrease reaches a minimum at the mesopause, which is the coldest part of the atmosphere with temperatures often well below  $-100^\circ\text{C}$ . This is a significant factor in the formation of noctilucent clouds.

## The Right Place and Time

Only clouds well above the troposphere can remain brightly lit after the Sun has set for an observer on the ground, and the combination of great height and high reflectivity keeps NLCs visible long after tropospheric clouds have ceased to receive direct sunlight.

To observe noctilucent clouds, you must be in the right place at the right time. The clouds are visible from middle to high latitudes during the summer months as the observer's hemisphere is tilted toward the Sun. Hence NLCs can be seen from May to August in the Northern Hemisphere, from November to February in the Southern Hemisphere, and occasionally outside these periods. The peak time is around, and preferably just after the summer solstice: June 21 in the Northern Hemisphere and December 21 in the Southern Hemisphere.

Although noctilucent clouds may be present any time, they only become visible during twilight. The clouds make their first appearance in evening twilight when the Sun drops  $6^\circ$  below the horizon. At this time the contrast between the brightness of the clouds and that of the sky makes the clouds clearly perceptible. This contrast is greatest when the Sun is about  $10^\circ$  below the horizon, and the clouds are then most prominent. After the Sun sinks more than  $16^\circ$  below the horizon, it no

longer illuminates the clouds, and they are no longer visible. The entire sequence is reversed as the Sun ascends before dawn and the solar depression angle — the angle of the Sun below the horizon — decreases from  $16^\circ$  to  $6^\circ$ . The display is generally weakest around local midnight.

The best latitudes for seeing the longest NLC displays are between  $50^\circ$  and  $60^\circ$  north and south. At higher than about  $60^\circ$  there are weeks or even months, depending on the latitude, on either side of the summer solstice when the Sun never sinks more than  $6^\circ$  below the horizon. NLCs may still be seen from these latitudes for short periods outside midsummer. In latitudes progressively lower than  $50^\circ$  the Sun sets and rises more steeply and therefore more rapidly, so the Sun spends less time between the solar depression angles of  $6^\circ$  and  $16^\circ$ , and the length of the observing periods are greatly reduced.

Most NLCs appear quite low in the twilight sky, usually around  $10^\circ$  above the horizon. But when the solar depression angle is  $6^\circ$  to  $8^\circ$ , the clouds can be observed beyond the zenith into the other half of the sky. Usually NLCs near the zenith are invisible, but the same clouds can often be seen lower in the twilight sky by observers 100 or 150 miles closer to the equator. When the Sun is about  $14^\circ$  to  $16^\circ$  below the horizon, the clouds are only visible very near the twilight horizon. On rare occasions seeing NLCs when the Sun is less than  $6^\circ$  below the horizon is also possible, but at these times noctilucent clouds are very difficult to distinguish from cirrus clouds.

Noctilucent clouds are most often seen from the Northern Hemisphere because it has a much greater land area and higher population density, particularly at the latitudes conducive to NLC observation, than the Southern Hemisphere does. The British Isles, Scandinavia, the Soviet Union, Canada, and Alaska are the major observing regions, although the clouds are sometimes observed from outside these areas. Observers as far north as Danmarkshavn, Greenland ( $77^\circ$  north), and as far



south as New York State (42° north) have seen NLC displays, so there are no strict latitude limits for visibility.

There are few places suitable for observing NLCs in the Southern Hemisphere. Only southern Argentina, southern Chile, the Falkland Islands, the northern parts of Antarctica, and a few islands in the southern oceans lie within the prime latitudes for seeing the clouds. Despite the small number of reported observations from the Southern Hemisphere, researchers believe the clouds occur there as frequently as in the Northern Hemisphere.

#### Early Observations

What are noctilucent clouds? Scientists have been trying to fathom the nature of these clouds since 1885, when the clouds were "discovered" during a series of extensive and brilliant displays. From then until the early 1890s astronomers Otto Jesse in Germany and Tseraskii in Russia made the pioneering studies. Both determined the altitudes of NLCs by triangulation, which involves different observers at different locations measuring the angular position of a single NLC.

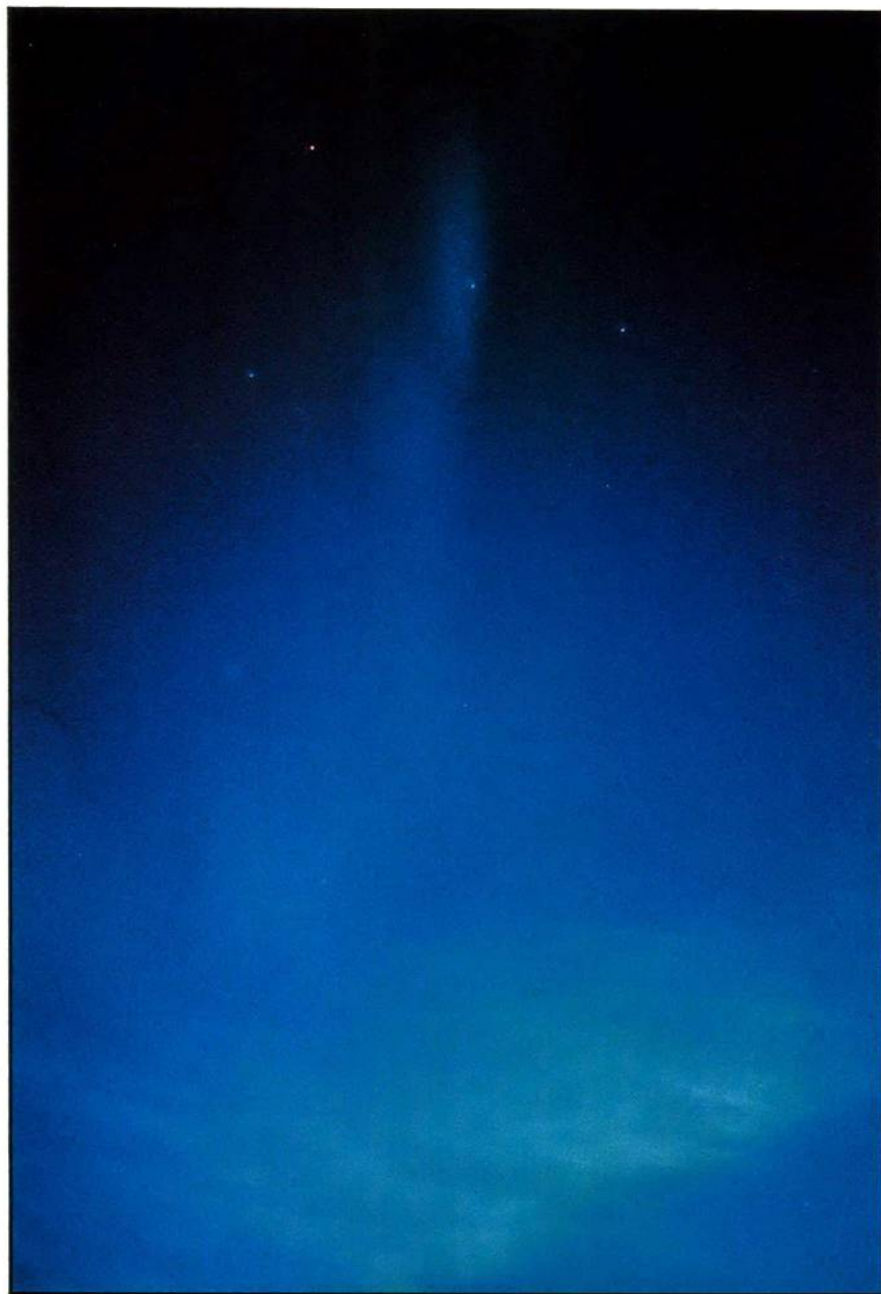
During that period researchers thought NLCs were of volcanic origin. The violent eruption in 1883 of Krakatoa in the East Indies spewed vast amounts of volcanic dust and gases into the atmosphere. This volcanic debris remained in the atmosphere for several years and produced spectacular sunrises and sunsets, and the appearance of NLCs in the twilight sky naturally led to the volcanic origin theory.

But doubts about whether volcanic material could be thrust upward to a height of fifty miles soon arose. And after the eruption of Katmai in Alaska in 1912, which was nearly as explosive as Krakatoa, there were no notable NLC occurrences. Moreover, brilliant displays of the clouds appeared just after the Tunguska impact in 1908. (The nature of the object that apparently broke up over the Siberian wilderness is still debated, although most astronomers suspect it was an asteroid or comet.) These displays encouraged the belief that NLCs have a celestial origin instead of a terrestrial one or, in other words, that noctilucent clouds are caused by meteor particles in the upper atmosphere.

Earth is continually bombarded by meteors at a rate estimated at hundreds of tons each year. Scientists believe that the dust so produced, which is then coated by water-ice crystals, forms the necessary condensation nuclei for noctilucent clouds just as a tropospheric cloud requires minute particles of dust, soil, salt, chemicals, or other substances in the lower atmosphere to act as condensation nuclei.

#### The Nature of NLCs

A great deal of research has been conducted over the last thirty-five years to determine the nature and origin of noctilucent clouds. During the International Geophysical Year, an eighteen-month



**Noctilucent clouds remain visible deep into twilight because the Sun still shines at an altitude of fifty miles, which is where the clouds are located. This photo records the rare, simultaneous occurrence of noctilucent clouds and an aurora. The stars of the Big Dipper shine in the background. Courtesy the Geophysical Institute, University of Alaska.**

period in 1957-1958 devoted to the study of Earth's environment during a sunspot maximum, scientists measured the high latitude mesopause temperature from Fort Churchill in Manitoba, Canada, at 59° north. These measurements confirmed that at high latitudes the mesopause was colder in summer than in winter with average temperatures of -103° C and -43° C, respectively.

This led to the theory that NLCs form when water vapor rises to the mesopause and freezes into ice clouds. The difficulty was explaining how water vapor could penetrate upward to the mesopause. But

research in the early 1960s showed that a circulation pattern could exist where moist air rises from the hot equatorial regions to a height of about fifteen miles, moves longitudinally toward the summer pole, and then ascends to fifty miles at high latitudes.

Even a rocket experiment launched from Sweden in 1962 by an American team from the Air Force Cambridge Research Laboratories failed to supply conclusive evidence of cloud composition. Designed to sample and collect noctilucent cloud particles, the experiment detected traces of nickel and iron that





A Type 1 NLC, or veil, lacks structure and appears tenuous or nebulous. There is also some wave structure (Type 3) visible in this cloud. Courtesy Geophysical Institute, University of Alaska.



David McConnell recorded the bandlike structure of a Type 2 NLC from Lincoln, England, at 53° north. He used a 55mm lens at f/1.2 and exposed for 2 seconds on Ektachrome 100. Note the dark tropospheric clouds in the foreground.







A Type 3 NLC, also called waves or billows, consists of closely spaced, parallel short streaks. Capella is also visible in this 1-second exposure taken in Scotland by David McConnell. The sky appears black only because of the short exposure and does not mean that NLCs are visible under black, nighttime skies.

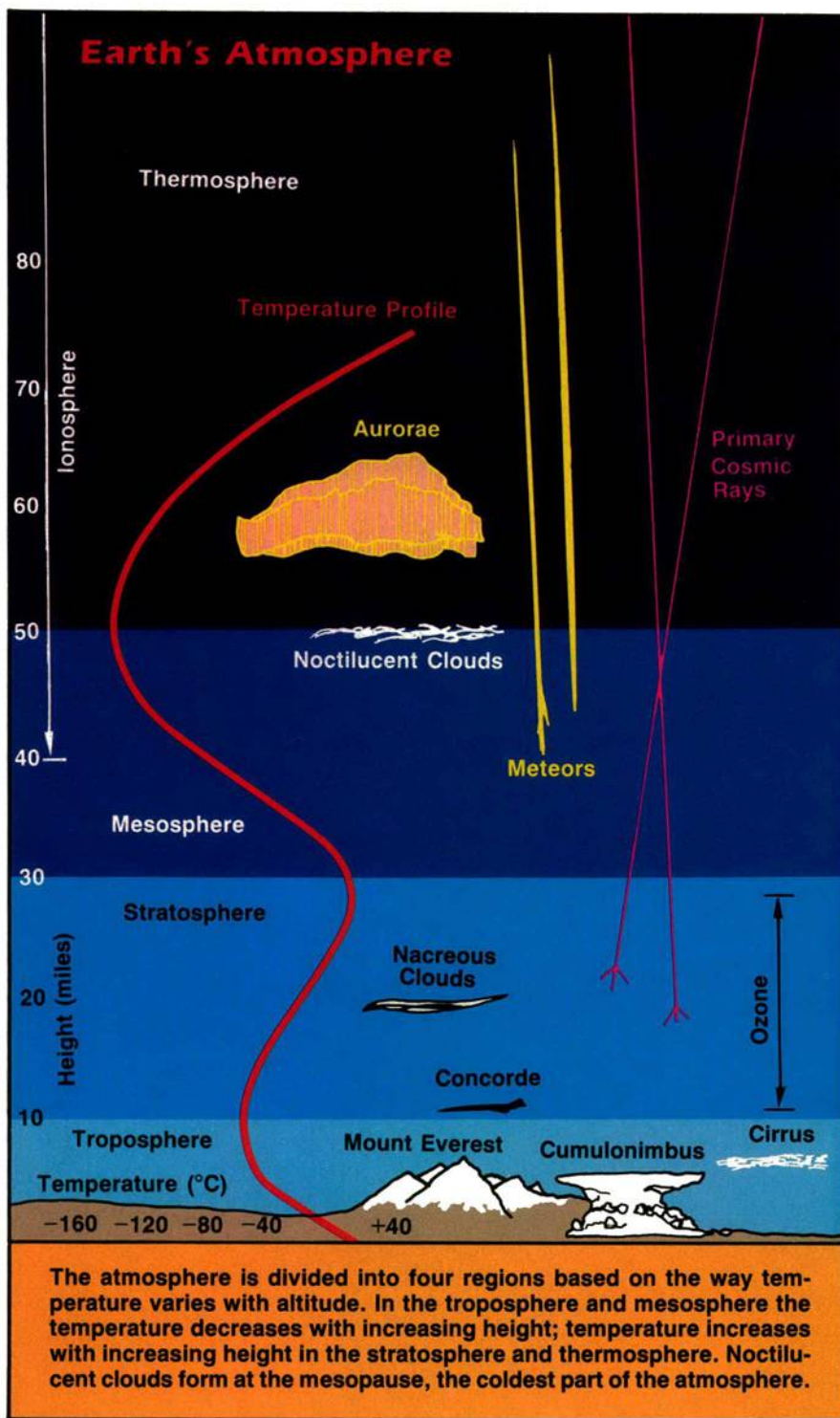


The contrast between the bright whirls of Type 4 NLCs and a band of dark tropospheric clouds highlights this image of the twilight sky. Mark Zalcik took this photo from St. Albert in Alberta, Canada, at 53.5° north with a 50mm lens at f/2.8 and a 1-second exposure on Kodacolor VR 1000.

Oscar Van Dongen captured this striking combination of Type 2 and Type 4 noctilucent clouds from Saskatoon, Saskatchewan, at 52.5° north. He used a 50mm lens set at f/2 and a 30-second exposure on Kodachrome II to record the scene. Capella is the bright star visible just above the clouds.







were suggestive of meteor dust, and some of the particles appeared to have a coating of ice. The relatively large diameter of the solid particles, ranging from 0.05 to 0.5 microns, also indicated an extraterres-

### Contributing to NLC Research

If you're interested in making serious observations of noctilucent clouds, contact David Gavine, the NLC coordinator of the British Astronomical Association at 20 Coillesdene Crescent, Joppa, Edinburgh EH15 2JJ, Scotland. He will supply you with observation sheets explaining how to report the clouds.

trial origin.

Further rocket research from 1963 to 1965 showed that the lowest temperatures — measured as low as  $-144^{\circ}\text{C}$  — did not necessarily produce noctilucent clouds. While such temperatures were a necessary condition for NLC formation, they alone were not sufficient. The other key factor was the amount of water vapor that reached the mesopause from the lower atmosphere.

In 1967 when a rocket captured far fewer solid particles than expected, researchers advanced an alternate mechanism for cloud formation. Instead of

meteor dust, ions could be the condensation nuclei on which ice is deposited. Ions — electrically charged atoms or molecules — form in the ionosphere, a region within the mesosphere and thermosphere where the reflection of radio waves takes place. Since there is an ample supply of nitrogen, oxygen, and heavier ions, including those of iron, at the mesopause, the new theory postulated that NLCs result from the clustering and freezing of water molecules around these ions when the temperature was about  $-140^{\circ}\text{C}$  and there was a high concentration of water vapor.

Orbiting satellites have also played an important role in the study of noctilucent clouds. The NASA Orbiting Geophysical Observatory satellite (OGO-6) made an important discovery in 1969 when it observed an extensive, dense but bright "scattering layer" at the mesopause over each of the summer polar regions. These layers, known also as "polar mesospheric clouds," were especially prominent above  $80^{\circ}$  latitude but lay over areas unsuitable for ground observation. Nevertheless, the scientists involved considered noctilucent clouds to be ragged extensions of these layers visible from lower latitudes.

The existence of polar mesospheric clouds remained unconfirmed until NASA launched the Solar Mesosphere Explorer satellite (SME) in 1981. The satellite observed the clouds and found that their brightness and extent increase above  $60^{\circ}$  north and south and that their thickness is less than two miles. However, even with very recent SME data there is still no direct evidence to support the belief that the particles are water-ice crystals. Other questions that remain to be answered about the layers include: Are they correlated with auroral activity? Are they controlled by phenomena in the stratosphere or troposphere? Are meteors important in the nucleation of particles?

The relationship between noctilucent clouds and aurorae seems to be an inverse one, which implies the two phenomena do not occur together for any significant time. Even though they have been observed at the same time from the same place, the NLCs usually suffer a reduction in brightness, extent, and structure soon after the onset of an aurora. Researchers believe this effect is caused by a heating of the mesopause by auroral electric currents. A warming of just  $10^{\circ}\text{C}$  to  $20^{\circ}\text{C}$  may be sufficient to disperse the NLCs.

Rocket measurements taken during the International Geophysical Year showed that the high latitude average summer temperatures at the mesopause were  $-108^{\circ}\text{C}$ . This is considerably warmer than the  $-143^{\circ}\text{C}$  recorded during the following solar minimum around 1964 and suggests there is also an inverse relationship between NLCs and solar activity.

### Observing NLCs

In contrast to twilight tropospheric clouds — even cirrus clouds — which



appear darker than the surrounding sky, noctilucent clouds glow with a silvery, often bluish color because they scatter sunlight better at shorter (blue) wavelengths than at longer (red) ones. Because their light comes from the Sun, the light shows a continuous spectrum without emission lines and with the dark Fraunhofer absorption lines. NLCs are never seen against either a black nighttime sky or a bright blue daytime sky: they are visible only against a twilight sky ranging from pale to dark blue. They are usually transparent enough to allow bright stars to shine through. Binoculars or a telescope at low power will darken the sky and thereby increase contrast, which offers observers a chance to see the clouds up to half an hour earlier than they would with their eyes alone.

There are four basic types of noctilucent clouds. Type 1 (*veils*), the simplest form, is tenuous or nebulous and lacks structure. Type 2 (*bands*) is made up of long streaks, either diffuse or sharp, that generally run parallel to one another. The bands can be several hundred miles long with separations of six to sixty miles. Type 3 (*waves or billows*) is closely spaced, parallel short streaks often lying across bands (like fish bones). The distance between the waves or billow streaks is approximately two to six miles. Type 4 (*whirls*) consists of twists, curves, or even rings of cloud material that may be seen in veil, band, or billow form.

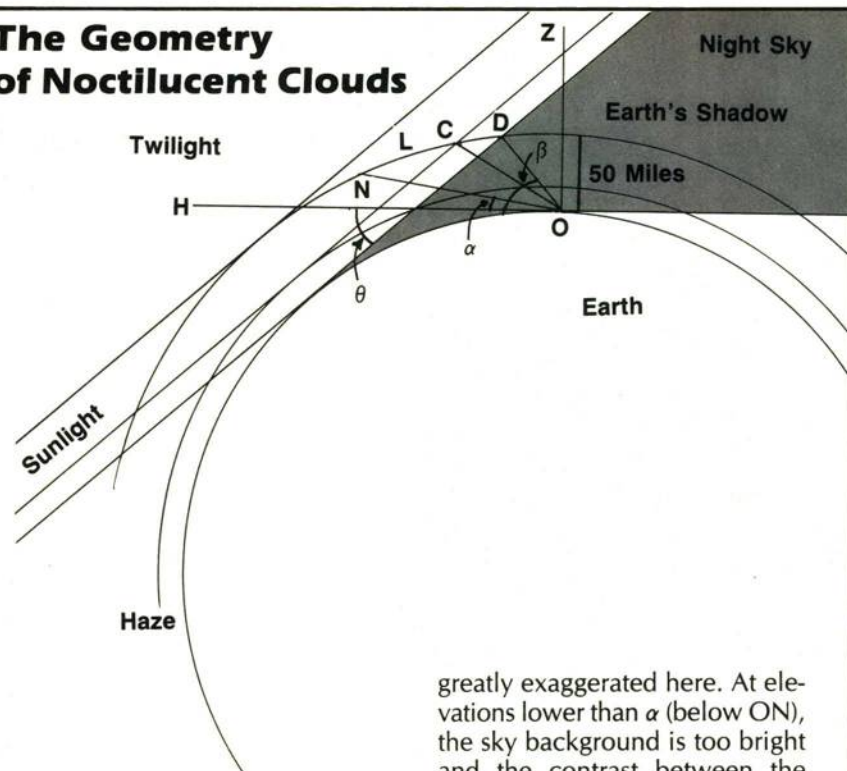
#### Capturing the Memory

Noctilucent clouds offer an amateur sky watcher the opportunity to obtain spectacular twilight photographs. The techniques are similar to those used for auroral photography. A 35mm single-lens reflex camera is the most convenient format, and the standard 50mm focal length lens is usually sufficient to capture the clouds. If the cloud display covers a large area of sky, a wide-angle lens, say 28mm or 35mm focal length, may be required to record its entire extent on one frame; if the NLCs cover only a small portion of the sky, a telephoto lens of 100mm or longer focal length can provide an image with greater detail. With whatever lens you use, however, try to include part of the horizon — trees, hills, buildings, town lights — so a proper perspective and scale can be determined. This horizon, moreover, can lend additional interest and pictur-  
esqueness to the whole scene.

Slow films can give excellent photos of noctilucent clouds. Because the clouds remain fixed in the sky, there are no inherent difficulties in the long exposure times that slow films require. And if tropospheric clouds are also present, the details in them will be accentuated on longer exposures. Of course, anyone who takes a photograph of NLCs and an aurora together has a major "scoop"!

Exposure times are best determined by trial and error. Set the lens fully open, focus at infinity, and then shoot a range of exposures depending on the speed of

## The Geometry of Noctilucent Clouds



Noctilucent clouds form at an altitude of about fifty miles and can be seen by ground-based observers under certain circumstances. This diagram (which is not drawn to scale) represents one such circumstance, where an observer (denoted by O) at an appropriate latitude can see the clouds somewhere between the twilight horizon OH and the zenith OZ.

In this situation the clouds are theoretically visible between the elevations  $\alpha$  and  $\beta$ , or in other words, between ON and OD over the arc NLC. The angles  $\alpha$  and  $\beta$  represent elevations above the horizon; the values of the angles depend on the solar depression angle  $\theta$ , which is ideally  $6^\circ$  to  $16^\circ$  and has been

greatly exaggerated here. At elevations lower than  $\alpha$  (below ON), the sky background is too bright and the contrast between the clouds and sky too low for an observer to clearly discern the NLCs. At elevations higher than  $\beta$  (above OD), the clouds are not illuminated by sunlight because they are within the Earth's shadow extending through D.

In reality there is a "haze layer" of height  $h$ , called the "screening height," above Earth's surface that further reduces NLC visibility. Sunlight passing through this haze layer, which can extend high into the troposphere, is greatly attenuated by scattering and absorption, so only the Sun's rays higher than this layer (extending through C) have sufficient intensity to illuminate the clouds. Thus, the greatest possible display of the clouds is over the arc NLC.

your film. With fast films you can probably record the clouds in a few seconds, while slow films may take a minute or more. In any case bracket your exposures by at least a couple of stops each way to make sure you get at least one good photo.

Noctilucent clouds are beautiful twilight phenomena visible every summer from the appropriate latitudes. Surprisingly, though, NLCs were not officially recognized until 1885 and, moreover, they were first reported from North America only in 1933.

Even today few astronomy enthusiasts

have observed these glowing twilight clouds. In the words of Mark Zalcik, a Canadian NLC photographer: "NLCs need all the exposure they can get." By observing noctilucent clouds, amateur sky watchers can provide important observational and photographic data while witnessing one of nature's most beautiful sights.

David McConnell is a Scottish amateur astronomer employed by the UK Meteorological Office at Lincoln, England. His last article for *ASTRONOMY* was "Basic Lunar Photography," published in the December 1985 issue.





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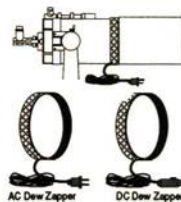
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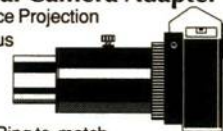
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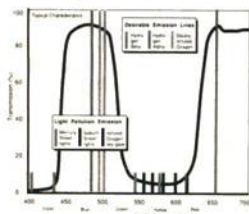


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## Eye on the Sky

# Mercury and Venus Vanish from View

by Robert Burnham

## The Wanderers

Except for a brief appearance by Mars, July's evening sky contains one naked-eye planet, **Saturn**. Lying among the stars of Ophiuchus, Saturn shines brightly over the trees in the southeast as darkness falls. You can spot it easily by comparing the star map (overleaf) with the sky. Only Antares in Scorpius could be mistaken for the planet, though Saturn is brighter, more ivory-white in color, and lies to Antares' upper left.

With some difficulty **Mars** can be spotted very low in the west soon after sunset during the first half of July as an amber dot shining at magnitude 1.8. But it lies so low that by the time the last touch of daylight has faded from the western sky, Mars is gone too. After roughly the second week of July, Mars will lie too close to the Sun to be seen at all. In the morning sky **Venus** will vanish into the Sun's glare at about the same date. Venus, however, is easier to spot before it disappears because it shines bright white at magnitude  $-3.9$ .

As morning twilight begins, the dim stars of Pisces lie high in the southeast with blazing white **Jupiter** among them. At magnitude  $-2.4$ , Jupiter has a brightness that instantly sets it apart from the stellar backdrop. Both Jupiter and Saturn are moving relative to the stars in their vicinity, but the planets move so slowly they appear almost fixed in place.

On its downward track Venus passes **Mercury**, now rising toward greatest elongation (July 25). On July 15, both planets will be  $1^\circ$  high in the east-northeast forty-five minutes before sunrise. Because  $1^\circ$  is too low for easy viewing, keep your eye on the much brighter object (Venus) as daylight grows stronger. Then, having found Venus, look  $6^\circ$  — approximately one binocular field — to the right for the

Looking southeast, July 8,  
45 minutes after sunset



2.3-magnitude reddish dot of Mercury. In the days thereafter, Venus will slip lower while Mercury climbs to an elevation of  $8^\circ$ , which it reaches a few days after greatest elongation. Mercury will remain in view until about August 10.

The **Delta Aquarid meteor shower** is a broadly diffuse event that reaches maximum activity in late July. Comprised of two barely distinguishable streams (the northern and the southern streams), the Delta Aquarids peak on the evening of July 28 this year. Best viewing, however, will come between 1 a.m. and dawn on July 29. This is four days after New Moon, so conditions should be nearly ideal for a fine display. At a dark-sky site a small group of sharp-eyed observers should net fifteen to twenty meteors an hour among themselves. The radiant lies near 3rd-magnitude Delta ( $\delta$ ) Aquarii, which rises around 10:30 p.m. daylight time in late July.

## The Starry Sky

This month the nights to learn the constellations will be in the first and last weeks of July, when the Moon sets early and when the Moon is "old" and doesn't rise until late. But don't waste these short dark evenings trying to view the stars near city lights. Instead, go out of town at least a little distance. A light sweater, a thermos of coffee, your July issue, and some bug

repellent are all you'll need. (A small flashlight with its lens dimmed by red paper will save your night vision while you read the map.)

You'll notice lots of stars right away, but after about twenty minutes, when your eyes have adapted to the dark, the **Milky Way** will become the dominant object in view. Nearly bisecting the sky, this ribbon of light from countless stars in our galactic disk is widest and brightest near your southern horizon. The division you see higher up is caused by a "nearby" cloud of dark dust that obscures the more distant stars.

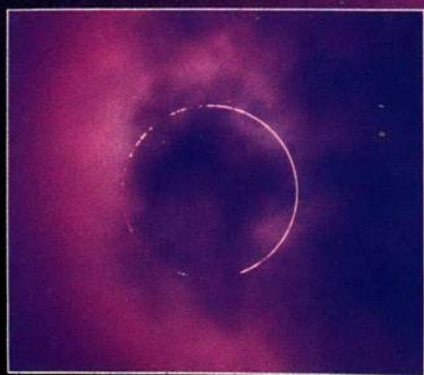
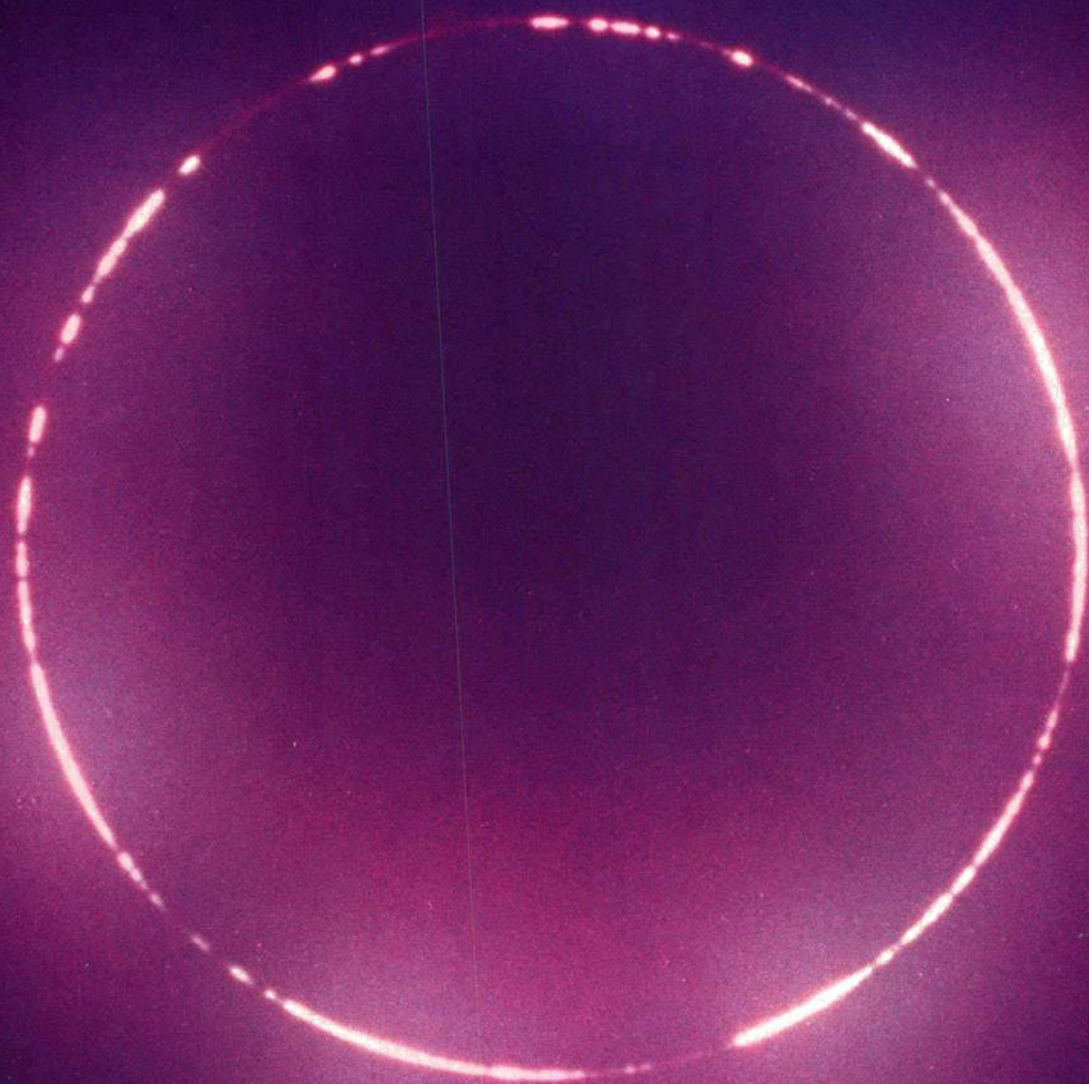
Looking due south, you'll see two bright objects over the trees. The one on the left is the planet Saturn, the other is Antares, a star that belongs to **Scorpius** the Scorpion (see Skylore). The jagged curl of Scorpius is a distinctive figure; the stars Beta ( $\beta$ ), Delta ( $\delta$ ), and Pi ( $\pi$ ) now mark its claws (long ago the claws included **Libra**

**Opposite page:** Despite cloud cover, high heat, and humidity, Huquette Guertin made these two exposures of the March 29 annular eclipse as a thin layer of clouds covered the Sun. A faint prominence is visible near the "top" of the disk.

**Inset:** This exposure was made five seconds earlier, just as a thick cloud covering was moving away from the disk. For both photos Guertin used an 89mm Maksutov-Cassegrain lens at f/11, ISO 100 35mm Kodacolor VRG film, and a 1/15-second exposure.

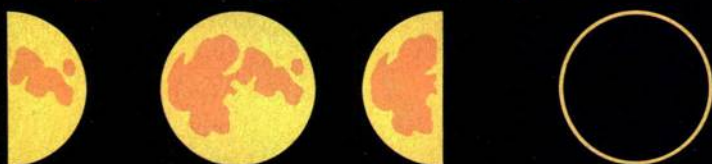
For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.





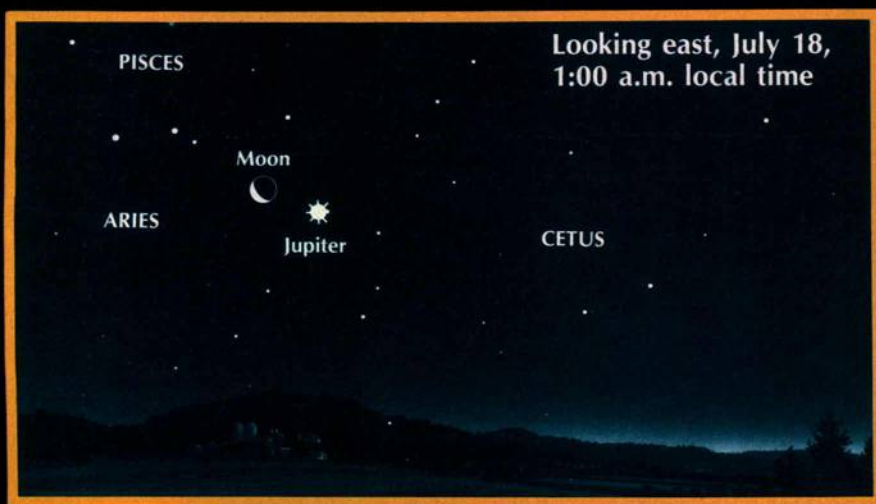


# July Night Sky



|                                          |                                        |                                          |                                      |
|------------------------------------------|----------------------------------------|------------------------------------------|--------------------------------------|
| First Quarter<br>July 4<br>4:34 a.m. EDT | Full Moon<br>July 10<br>11:33 p.m. EDT | Last Quarter<br>July 17<br>4:17 p.m. EDT | New Moon<br>July 25<br>4:37 p.m. EDT |
|------------------------------------------|----------------------------------------|------------------------------------------|--------------------------------------|

- 3rd** Earth is at its greatest distance from the Sun: 94.5 million miles (152.0 million kilometers).
- 4th** Mercury passes between the Sun and Earth, moving from the evening sky into the morning sky. It will become visible low in the northeast before sunrise in about two weeks and can be seen there until early August. First Quarter Moon is at 4:34 a.m. EDT.
- 7th** Mars is about to vanish from the evening sky as it approaches the Sun. Mars will reappear in the morning sky in October, rising just before the Sun.
- 8th** The Moon lies close to Antares and Saturn this evening (see diagram on page 50).
- 10th** The Moon is Full at 11:33 p.m. EDT. Jupiter is at its closest to the Sun: 460.3 million miles (740.7 million kilometers).
- 11th** The Moon is nearest to Earth at 6:40 a.m. EDT: 221,856 miles (357,032 kilometers).
- 12th** Mercury and Venus lie 5° apart in the morning sky.
- 15th** In a few days Venus will disappear into the morning twilight and will not be seen again until late September, when it reappears in the evening sky.
- 17th** Last Quarter Moon is at 4:17 p.m. EDT.
- 18th** The Moon passes 4° north of Jupiter.
- 25th** The Moon is farthest from Earth at 3:47 a.m. EDT: 252,622 miles (406,608 kilometers). New Moon occurs at 4:37 p.m. EDT. Mercury is at greatest western elongation from the Sun in the morning sky, but Mercury's best visibility comes on the 29th.
- 29th** The Delta Aquarid meteor shower reaches peak activity in the predawn sky. Mercury is at best visibility in the morning sky.



Looking east, July 18,  
1:00 a.m. local time



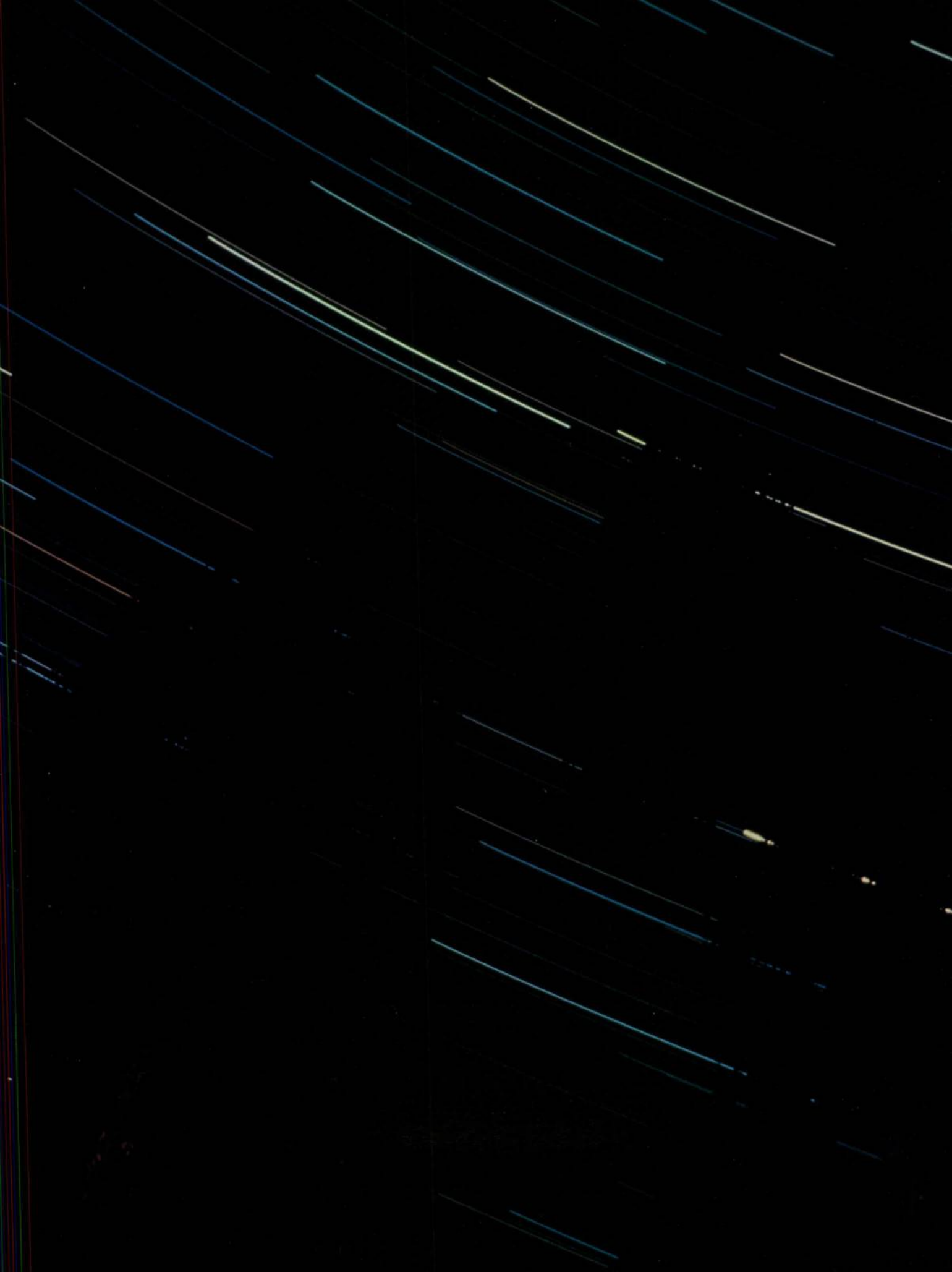
The  
Star Dome  
shows how the  
sky looks at:

Midnight on July 1  
11:00 p.m. on July 15  
10:00 p.m. on July 31











Opposite page: Notice the different colors of the stars revealed in this star-trail photo by Jay Small, who used a 50mm lens at f/1.7, ISO 400 film, and a 1-hour exposure. Right: The starcloud in Scutum, north of Sagittarius, stands out to the naked eye on a midsummer's night. Photo by Rev. Ronald E. Royer.

the Balance). Antares is its heart (or eye), while the body continues through Tau ( $\tau$ ), Epsilon ( $\epsilon$ ), Mu ( $\mu$ ), and Theta ( $\theta$ ) to end in the deadly stinger, a star called Shaula, which is marked Lambda ( $\lambda$ ) on the map.

The celestial Archer **Sagittarius** lies to Shaula's upper left. The main asterism resembles a teapot, though its outlying stars circle eastward and down around **Corona Australis** the diminutive Southern Crown. Try scanning with binoculars through the Milky Way "steam" rising out of the teapot's spout. Many clusters and nebulae throng this region, behind which lies the center of the Galaxy.

Following up the Milky Way, we find **Scutum** the Shield — poor in bright stars but rich in clusters. Then comes diamond-shaped **Aquila** the Eagle with its landmark star 1st-magnitude Altair. Past **Sagitta** the Arrow and the Little Fox **Vulpecula** lies **Cygnus** the Swan. Deneb is eye-catching, but take a moment to trace the figure that also bears the name the Northern Cross. Its neighbor to the west is **Lyra** the Lyre, looking almost miniature in comparison. Vega in Lyra, together with Deneb and Altair, form "The Summer Triangle," an asterism prominent from now on into autumn. To the west of Lyra the famous strongman **Hercules** is poised upside down, his body forming a keystone (distinctive once you see it) with his arms extending south and his legs north.

Over in the northeast, **Cepheus** the King of Ethiopia and **Cassiopeia** his Queen mark where the Milky Way slips toward the horizon. Cepheus looks sort of like a stretched home plate or a child's drawing of a house (now tipped on its side); Cassiopeia is a wide W. To the left of Gamma ( $\gamma$ ) Cephei lies Polaris the North Star. It sits at the end of the handle of the Little Dipper or **Ursa Minor** the Lesser Bear.

Flanking Polaris on its left is the bowl of the Big Dipper, familiar to nearly everyone. The Dipper is made from the brightest stars of the Great Bear **Ursa Major** and is the dispersed remnant of an old star cluster. If you follow the curving handle of the Dipper outward, your eye naturally falls on Arcturus, the 1st-magnitude luminary of **Bootes** the Herdsman. Its tall, tippy shape resembles a skinny kite. Near its widest point, a small circlet of 3rd- and 4th-magnitude stars called **Corona Borealis** resembles its name, the Northern Crown.

Our last stop tonight is Spica, the bright ear of wheat in **Virgo** the Maiden's hand. You'll find Spica by extending that curved line from the Dipper's handle through Arcturus onward about the same distance.



Virgo is dim and can be hard to trace because it lacks an obvious shape. But at least you'll find Spica readily.

## Skylore

*Te ika a Maui*, "the fish of Maui," is the native name for New Zealand. It commemorates an event celebrated in the mythologies of New Zealand, the Tonga Islands, Hawaii, and other parts of Polynesia. Maui was a heroic, Promethean figure. Like his Greek equivalent he brought fire to mankind, and like Coyote (in native American traditions) Maui was also a trickster renowned for his slyness.

One day, so the story goes, he went fishing with a hook he had "borrowed" from his brothers, who were a pack of stupid fellows much older than Maui. Maui had baited his hook with a jawbone given to him by the ancestral goddess who lived at the gates of the underworld. Smearing the jawbone with his own blood, Maui attached the jawbone to his hook and cast it where the waters were deepest.

When all his fishing line had been paid out, Maui's hand immediately felt that distinct tug known to all fishermen. Delighted to have made a catch so quickly, he tried to haul in the line. But it wouldn't budge. He pulled and pulled but to no avail. Now curious to see what he'd caught, Maui dove into the ocean and followed the line down. Reaching bottom, he discovered the hook was stuck fast in the mud. After much effort he finally worked it loose and, after swimming back to the surface, began hauling in the line.

Imagine his surprise when, along with the hook, up came a gigantic fish covered with trees, houses, and people! Daily life on this fish was going on uninterrupted, just as if nothing extraordinary had happened. Cooking fires were burning, children were running around chasing pets, men were hunting pigs, women were weaving tapa cloth, and so on. A bright new country had been born from the depths of the sea.

Maui was so jubilant about his great achievement he began to dance. Round and round he spun, crying out with delight and proudly waving the wonderful fish-hook over his head. Seized with exuberance, he madly flung the hook away, far up into the heavens where it caught on the sky. Still stuck there to this day, we know it as the constellation **Scorpius**.

A look toward the south this evening will show you Maui's magical hook sparkling against a velvet backdrop. The haft where the line was attached is formed by the stars Beta ( $\beta$ ), Delta ( $\delta$ ), and Pi ( $\pi$ ) **Scorpii**. (These are the Scorpion's claws in Western mythology.) Red Antares marks the drop of Maui's blood used as bait, while the barbed hook itself is clear to see.

And if you doubt the truth of this fable, even just a bit, simply open a world atlas to the New Zealand map. The fish is no longer whole because Maui's stupid brothers started chopping it up to eat before he could stop them. (Thus the land has its famed fjords and valleys.) But can you see the fish's head pointing south? With its great forked tail flapping in the north? If not, simply squint a little and there it is — *te ika a Maui*.



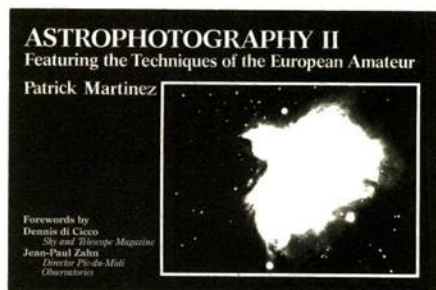
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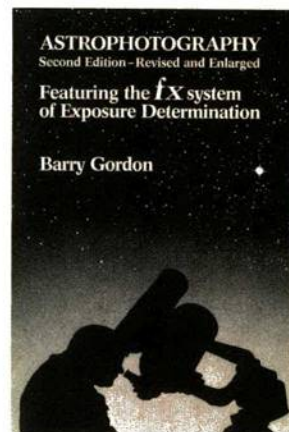
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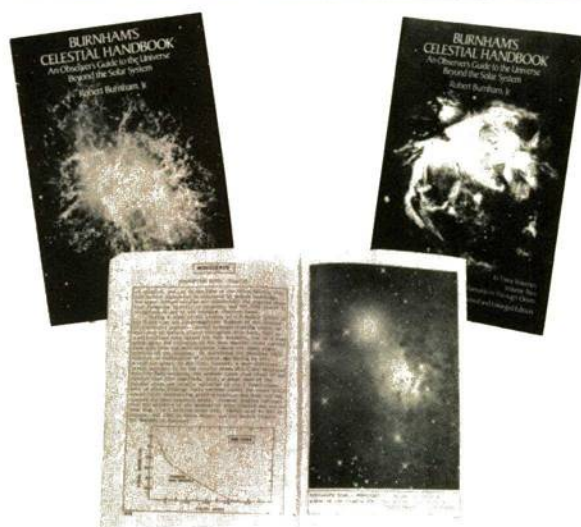
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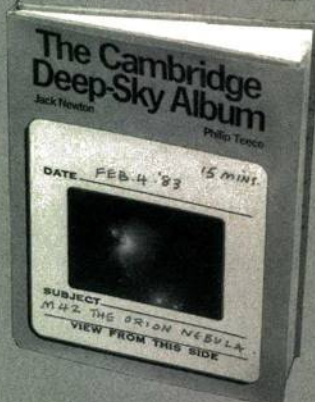
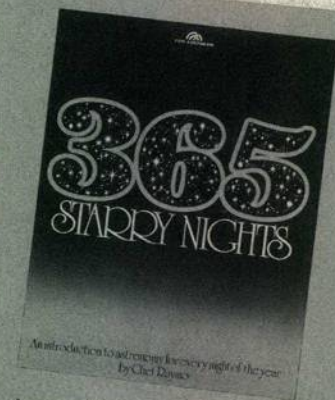
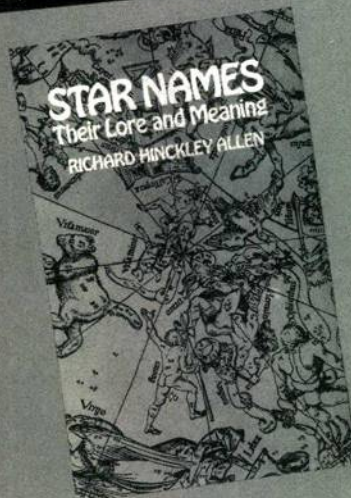
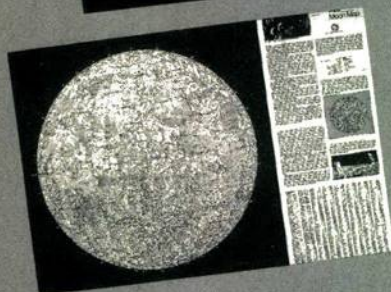
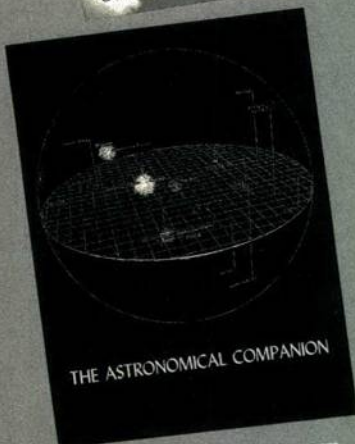
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# Photographing the Southern Sky

by Simon Tsang

In April 1986 I traveled from my home in Canada to South America. The prime attraction, and the reason I went at that time, was Comet Halley. I wanted to see it and to make a photographic record of its passage. But I also wanted to see the southern constellations and the rich stretch of Milky Way between Sagittarius and Puppis, parts of the sky lost to Canadians, and bring them all home with me on film.

I favored South America for its relative proximity and finally chose La Serena in Chile. Although I worried a bit about the language barrier, I would be traveling with a group of amateur astronomers from Houston on a guided tour, so fluency in Spanish would not be essential.

Known among astronomers for superb observing conditions, La Serena lies at just the right place in the worldwide pattern of air flow. The best observing conditions on our planet occur 30° north or south of the equator, atop isolated peaks on the westernmost mountain range of a continent, or on mountainous islands with a large ocean to the west. (The observatories in California, Australia, and the Andes are sited on mountain ranges; Mauna Kea and La Palma are island sites.) In addition, the observing site must also be higher than the inversion layer, which occurs at an elevation of 3,500 to 6,500 feet, depending on the distance from the coast and on the local topography.

La Serena is a small town located on the Pacific coast of Chile. It is often covered by very cool, low-lying clouds and fog caused by cold ocean currents off the coast, but this moisture cannot advance too far inland because of the Andes Mountains to the east and the warm, dry air that comes from tropical convection. Consequently, the nearby high-altitude sites enjoy three hundred clear nights a year, and the low clouds partially shield the nearby mountains from the light pollution of coastal towns.

In addition to first-class observing conditions, I considered the chance to visit the world-class observatories in the area

another plus. Cerro Tololo Interamerican Observatory boasts a 4-meter reflector, the largest telescope in the Southern Hemisphere. The European Southern Observatory has a 3.5-meter instrument, and Las Campanas has a 2.5-meter telescope, with more to come. For obvious reasons professional observatories are only open during the day to visitors and by appointment, so we were on our own in finding observing sites.

Our group observed for three nights with other tour members on 3,500-foot coastal sites just west of Cerro La Silla where the European Southern Observatory is located. Cold downdrafts from the 7,800-foot peak made the seeing quite turbulent. It was also occasionally hazy because of the interaction with the moist ocean air, and it was somewhat chilly.

For the later part of my observing run, I rented a car and made the bumpy drive along a treacherous mining road on my own to a 5,000-foot peak called Cerro Blanco, about twenty-five miles from the coast. The air there was quite calm, and the temperature was comfortably above freezing. Some city light was visible, but it was not detrimental. Because I was alone I could devote all night to photography. Working dusk to dawn, stopping only when the zodiacal light gave way to morning twilight, was wonderful.

The prime attraction for most observers, unquestionably, was Comet Halley. Unfortunately, the most impressive view had occurred on the night of March 18/19, just before dawn, when the comet's tail stretched 12° to 15° across the sky. It had been videotaped by Cerro Tololo astronomers and the tape was still being shown to visitors.

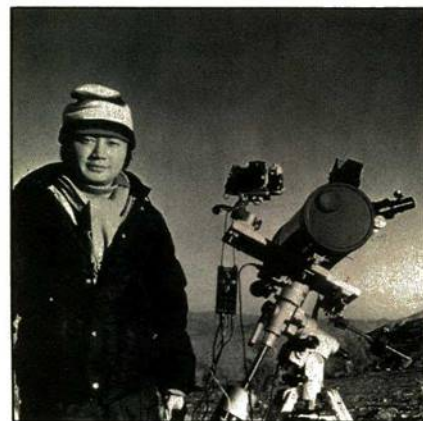
At the time I was there, between April 9 and 15, Halley was closest to Earth, but its tail pointed away from Earth and the comet did not appear as spectacular as many people had hoped. On the night of April 10/11 the coma was quite prominent in binoculars, appearing slightly smaller than the Moon. The tail appeared very wide and wedge-shaped but was

only 3° to 5° long. It culminated about 15° south of the zenith around midnight.

In any case, the true glory of the southern sky was not Comet Halley but the Milky Way. Along this rich corridor lie countless open clusters, globular clusters, diffuse emission nebulae, and dark nebulae, all within easy reach of small telescopes. Little wonder the Carnegie Institution is planning an 8-meter telescope at Cerro Las Campanas, an 8,200-foot peak one hundred miles north of La Serena.

Besides seeing the southern objects, I wanted to go home with a collection of photographs of them. I took a well-made equatorial mounting with a clock drive, a 6-inch f/3.6 Schmidt-Newtonian telescope with a 2-inch-diameter focuser, a small guide telescope, and a variety of camera lenses with me. Everything had to be portable, light, and self-contained.

I found that a little care and planning really paid off. I selected an energy-



**Above:** The author and his astrophotographic setup on Cerro Blanco.

**Right:** Using Fujichrome 1600D slide film with a 28mm f/3.5 wide-angle lens, Simon Tsang captured the star-rich hub of the Milky Way in Sagittarius and Scorpius in an 8-minute exposure. North is at the top and east is to the right.













Opposite page: The Coalsack dark nebula and the constellation Crux are among the most magnificent southern sky sights. Tsang used a 3.5-minute exposure with his 135mm telephoto lens at  $f/2$  on Fuji 1600D.

Above: The Large Magellanic Cloud was recorded in a 5-minute exposure with the 135mm lens at  $f/2$  on Fuji 1600D.

Below: Omega Centauri at the 550mm prime focus of Tsang's 6-inch  $f/3.6$  Schmidt-Newtonian. He used an 8-minute exposure on Fuji 1600D film.



efficient stepping-motor drive for my mounting; a set of six alkaline D-cells ran it for sixty hours in the field. This freed me from worrying about recharging batteries and all the problems associated with odd voltages, foreign plugs, and so forth. The control box has a switch to reverse the motor for Southern Hemisphere tracking — I made sure it had this before I bought it. Quartz drives tend to be quite accurate, so guiding was unnecessary with 135mm and shorter lenses.

For serious astrophotography, accurate polar alignment is crucial. Unfortunately, the area around the southern pole is devoid of bright stars; there is no Polaris in the Southern Hemisphere. Nevertheless, the pole is not difficult to find: it lies near a string of 8th-magnitude stars forming a semicircle near the magnitude 5.5 star Sigma Octantis. Because my mounting has a finder scope built into the R.A. axis, I simply set the cross hair on the spot where I knew the south celestial pole was.

For exposures with the 6-inch Schmidt-Newtonian I brought a short-focus 60mm refractor with a 3x Barlow lens. Although an off-axis guider would have been better in some respects, I decided against using one. Because I wanted to photograph Comet Halley, I needed a separate guider because the nucleus cannot be on the film and in the off-axis guider field at the same time.

April was a fine time to observe the bulk of the spectacular southern objects. In the early evening, Orion, Canis Major, and Puppis shone in the west, and by midnight the Sagittarius/Scorpius region glittered in the east. The in-between segment of the Milky Way that flows through Vela, Carina, Centaurus, Crux, Circinus, and Norma stayed high above the southern horizon almost from dusk to dawn. Because of the large number of bright stars in this part of the sky finding my way was not easy at first, but I soon learned to recognize the southern constellations. Incidentally, from La Serena we could see as far north as Cygnus, and part of the Big Dipper was visible.

My equipment arrived a day late, so I had to observe with 7x50 binoculars and a borrowed 13-inch open-frame Dobsonian telescope the first night. Still, it was a night I won't forget. Omega Centauri was nearly overhead, a fuzzy-looking star shining at magnitude 4.5, easily seen with the unaided eye. With binoculars it appeared oval. In the 13-inch Dobsonian at 120x it was the most spectacular globular cluster I've ever seen: it had no obvious dark lanes and the core was partially resolved. In appearance it was comparable to my view of M-13 at 350x in a 16-inch telescope in Ottawa but with three to five times the density of stars. All in all, Omega Centauri is a breathtaking sight.

Five degrees north of Omega is Centaurus A (NGC-5128), a peculiar elliptical galaxy. It appears 7th-magnitude in binoculars; with the 13-inch telescope the







two bright hemispheres are separated by a dark lane of uneven width visible even at moderate powers. This dark lane is wider and more conspicuous than the dark lane in the Sombrero Galaxy in Virgo.

Directly overhead we saw M-83 in Hydra. In binoculars this famous southern face-on spiral galaxy appeared diffuse and faint, rather like M-33. I detected two arms in an 8-inch telescope and a hint of the fainter third arm with the 13-inch Dobsonian.

Everybody who travels south of the equator wants to see Crux, the Southern Cross, but only an amateur astronomer knows to look for the Coalsack. From a dark-sky site I think this huge dark nebula in the Milky Way is more apparent to the naked eye than the adjacent Cross is. Spanning 6°, the Sack looks like an inky black stain in the brilliant Milky Way, whereas Crux is just four stars. The Coalsack is impressive in binoculars, a nearly starless region that fills the whole field of view. A little more optical aid reveals that it's not totally dark: with an 8-inch telescope at low power I could see numerous faint foreground stars.

To the southeast of Beta Crux lies the Jewel Box, a loose, bright open cluster around the star Kappa. The cluster is easy in binoculars but was better resolved with my 6-inch at 60x. I saw a single, bright red star set among seven or eight yellow-white and blue-white stars, which made a very colorful contrast! At higher powers two dozen fainter stars were visible.

Eta Carinae is by far the best and bright-

est emission nebula in the sky. This bright nebulosity in the Milky Way is visible to the unaided eye as a hazy patch. It is outstanding in binoculars and astounding in a large telescope. Eta Carinae has the high surface brightness of the Orion Nebula but spreads over an area three times larger. To view all of it I had to scan the 13-inch across it — and that was at low power. The nebula is segmented by prominent dark lanes and has a dark patch (the "Keyhole") just west of the star Eta. With its beautiful swirling outer extensions, this is without doubt the most splendid emission nebula I've ever seen!

Even before the recent supernova, the Large Magellanic Cloud had the power to lure us northerners south. Six degrees across, this dumbbell-shaped naked-eye galaxy has a surface brightness comparable to a faint section of the Milky Way. Binoculars reveal several condensations within it. The most notable of these are the cluster NGC-1910 (which includes S Doradus, one of the brightest stars known) and the Tarantula Nebula. The Tarantula appeared well-resolved in the 13-inch at 120x with extensions going in six directions, some looping like an insect's legs. What eerie charm!

Our Galaxy's second companion, the Small Magellanic Cloud, lies at 70° south declination and is an easy naked-eye object. The SMC is only half the size of the LMC, has a lower surface brightness, and in binoculars is shaped like a reversed comma. In my 6-inch scope at low powers I could see the clusters NGC-346 and NGC-371 near the apex, and I found NGC-362 1.5° north of the pair, outside the galaxy.

Last but not least is 47 Tucanae, a bright globular cluster 3° west of the SMC. Although its total brightness is about the same as that of Omega Centauri, it is slightly smaller, more concentrated toward the core, and requires higher power to resolve. It was low most of the night, but I still consider it the second finest globular in the sky.

Just before morning twilight set in, the Sagittarius region culminated at the zenith with the full panorama of the galactic disk stretching toward the northeast and southwest horizons. The sky was a close-up view of a fine edge-on galaxy, a sight I'll never be able to forget.

Generally I prefer slide films for astrophotography because they have a larger dynamic range than prints. Accordingly, I used Fujichrome 1600D film and occasionally Fujichrome RD100, both without hypering. The 1600D film is designed to be pushed two stops above its intrinsic ISO 400 speed to obtain the optimal color balance. I found that the first development time should be 13 to 13.5 minutes to obtain the rated speed of 1600 and that further push processing does not increase the speed to 3200 or 4800.

My favorite lens is a 5-element 135mm f/1.8 telephoto, which I normally stop down to f/2 for improved sharpness. This

lens influenced my choice of film. The 1600D film works well with fast optical systems, such as my 135mm f/2 telephoto lens, and gives nice color balance and high contrast. Except when I grossly overexposed it, the Chilean sky background on 1600D looked black, which I find satisfying. However, this film's high contrast tends to de-emphasize fainter objects. Furthermore, it is not as sensitive in the red as Fujichrome 100 is at the equivalent exposure level, so bright emission objects like the Eta Carinae Nebula appear dimmer than they should.

At focal ratios of f/4 or f/5, however, 1600D's speed drops noticeably in the blue-green and disastrously in red light because of reciprocity failure. What is reciprocity failure? Make a series of test shots, stopping the lens down and compensating for this by increasing the exposure. Shoot 10 minutes at f/2, 20 minutes at f/2.8, 40 minutes at f/4, and 80 minutes at f/5.6. Although the exposures are equivalent, the longer exposures will turn out underexposed: that's reciprocity failure. Hypersensitizing film ameliorates reciprocity failure, but it shortens the storage life and lightens the background, so I decided against it.

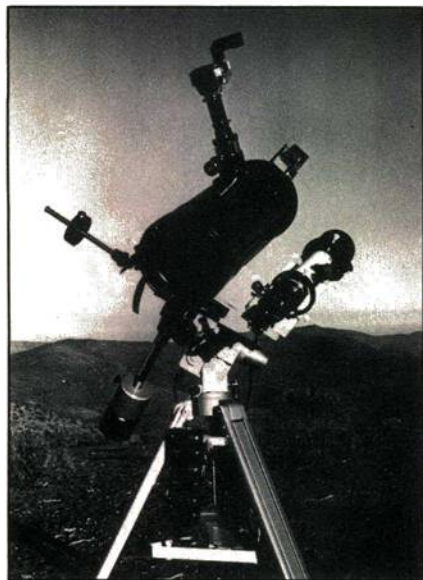
I based exposure times on experience I've built up at home in Canada. With unhypered Fujichrome 400D film I normally reach sky fog in 10 minutes — without filters — in my rural observing site on a fairly good summer night. I use this 2-4-10 combination (f/2 with 400 ISO for 10 minutes) as my reference exposure. Under poor conditions or in the winter when the sky is brighter because the light is scattered by snow on the ground, I limit my exposures to half or quarter the reference exposure.

For most of my Milky Way shots I shot at my reference exposure adjusted for slower film (Fujichrome 100 at f/2 for 40 minutes) or slower optics (Fuji 1600D with f/3.5 lens for 8 minutes). The combination of the dark sky and the high contrast of the 1600D allowed me to use 1.5 times the reference exposure (3.5 minutes) to saturate intragalactic objects with the 135mm f/2 lens. The LMC, which is fainter than the Milky Way, required 2.0 times the reference exposure, and the SMC 2.5 times greater exposure.

The southern heavens are a treasure house for deep-sky lovers, and Comet Halley and Comet Wilson, as well as Supernova 1987A, were the icing on the cake for those who live there and for lucky observers who traveled "down under" to see them. For me the trip fulfilled a long-time dream — and I look forward to another trip south of the equator.

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*Originally from Hong Kong, Simon Hoi-Chuen Tsang was educated in the United States and now lives in Ottawa, Ontario. He is a member of the Royal Astronomical Society of Canada, an engineer by profession, and a colleague of Rolf Meier, a comet hunter who has discovered four comets.*



**Opposite page:** The Eta Carinae Nebula lies in one of the brightest and richest sections of the Milky Way. Tsang recorded it with a 135mm telephoto lens at f/2 on Fuji 1600D slide film. He used a 3.5-minute exposure. (East is at top, north to the right in this photograph.)

**Above:** Tsang's telescope set up for astrophotography with a 3x Barlow lens. Note the short-focus guide telescope.



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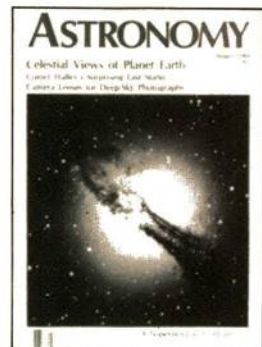
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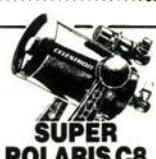
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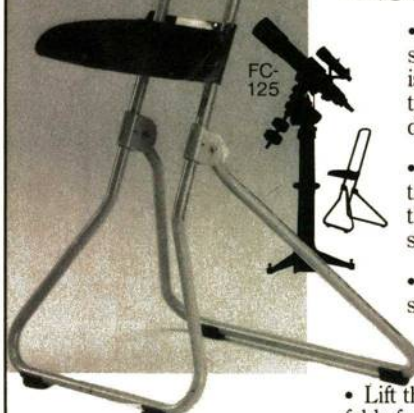
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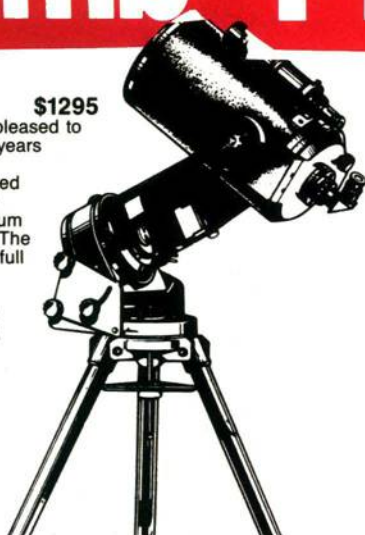


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# ASTRONOMY

## AstroNews

### SUPERNOVA UPDATE

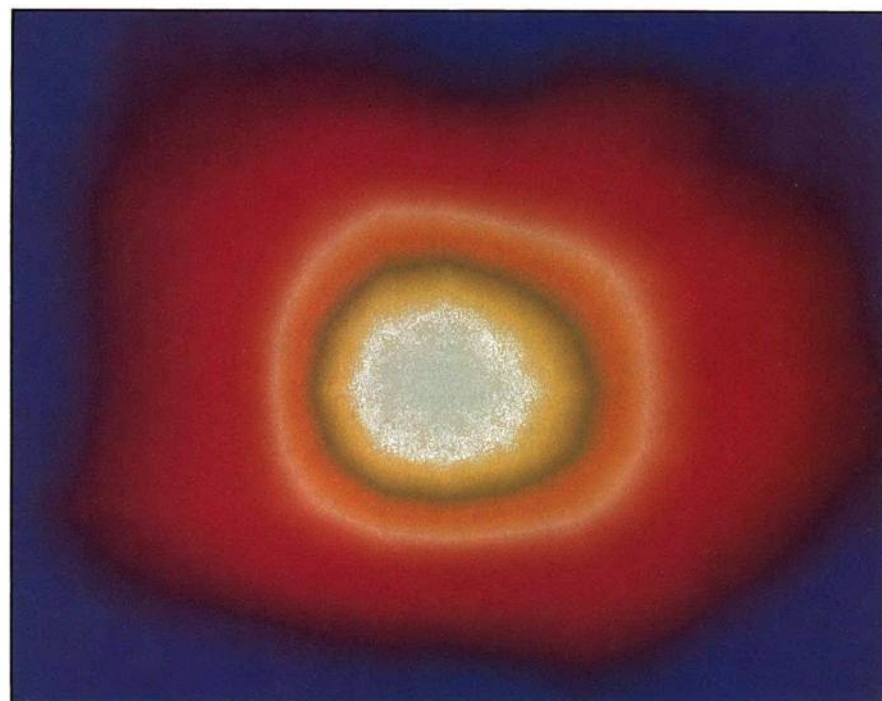
#### Brightening Continues; Progenitor Star Found?

Nearly two months after the February 24 explosion of supernova 1987A in the Large Magellanic Cloud (see "A Burst of Discovery: The First Days of Supernova 1987A" by Richard Talcott, *Stellar Frontiers*, June 1987), astronomers were still struggling to interpret the flood of observational data. Here are three significant findings to come from the second month of study.

- The unique behavior that has characterized the outburst from the beginning showed no signs of ending. Nowhere was this more evident than in the light output from the supernova. After an initial period of nearly constant brightness, or a plateau phase, 1987A began to slowly brighten around mid-March. At the beginning of April the supernova was slightly brighter than 4th magnitude visually, and by the middle of the month the brightness had climbed close to magnitude 3.5.

Gerard de Vaucouleurs of the University of Texas and Paul Murdin of the Royal Greenwich Observatory suggested soon after the explosion that 1987A might brighten after an initial plateau phase, much as the supernovae 1940B and 1941A had. But the observed pattern of brightening did not fit this scenario: the increase was much too gradual, and the magnitude in mid-April was still a magnitude and a half dimmer than that projected for late March.

In early April Alain Porter of the California Institute of Technology cast doubt on the very observations that led to de Vaucouleurs and Murdin's proposal. Pre-maximum observations of supernova 1941A consisted of just one precise brightness measurement and one upper limit to the supernova's brightness, while there were no precise measurements and five upper limits on supernova 1940B's brightness. Porter concluded that no substantial evidence exists for a premaximum plateau phase in these two supernovae;



Comet Wilson, shown here in a false-color, ultraviolet-light image taken from the Pioneer 12 spacecraft on March 17, appears to be a "major comet," according to Ian Stewart of the University of Colorado. Stewart, Pioneer's chief experimenter for comet study, reports that Wilson appears to be larger and more active than many previous comets. He estimates that Wilson's nucleus is 5 kilometers across; Comet Halley measured 8 by 14 kilometers. Wilson's gas is rich in carbon monoxide: 33 percent of the gas is CO and only 67 percent is water. Only 10 percent of Halley's gas was CO. NASA image.

therefore, the brightening of 1987A is unique.

- Some three hours before the supernova's light first reached Earth, underground detectors in Japan and the United States simultaneously recorded a burst of neutrinos. These observations are important not only because they open a new window on the collapse of a star's core, but because they offer a new way to determine the mass of the neutrino.

Scientists have debated for years about whether the neutrino has a mass. If not, neutrinos would travel through space at

the speed of light. But if the neutrino has even the slightest mass, it must travel slower than the speed of light, and more energetic neutrinos would move faster than less energetic ones. Because the Kamiokande-II experiment in Japan observed eleven neutrinos of various energies at slightly different times, scientists expected this data to be useful.

In an article in the April 2, 1987, issue of *Nature*, John Bahcall of the Institute for Advanced Study at Princeton and Sheldon Glashow of Harvard University reported on their calculations showing



that the neutrino mass must be less than 11 electron volts. If confirmed, this value suggests that neutrinos are not the dominant form of matter in the universe and, thus, that they alone cannot halt the expansion of the universe.

• The search for the star that actually exploded has now come full circle. Astronomers first thought the progenitor was the blue supergiant star designated Sanduleak (Sk) -69°202. Less than a week after the explosion, however, observations made from the International Ultraviolet Explorer (IUE) satellite indicated that Sk -69°202 was still shining normally and thus couldn't be the progenitor. Unfortunately, there were at least two other stars in close proximity to Sk -69°202, and determining which of these might be the progenitor was a major task.

By April 1, astronomers from the European Southern Observatory and Copenhagen University Observatory determined accurate positions for all three stars and compared these positions to that of the supernova. They concluded that Sk -69°202 lay between the other two stars and was closest to the position of the supernova. Furthermore, they found no evidence for a fourth star in this small area.

Two teams of IUE researchers then used this information to re-examine their earlier data. The distance separating the two sources of short-wavelength ultraviolet radiation they detected after the supernova faded below their instrument's threshold was inconsistent if Sk -69°202 was one of the sources. They also learned from long-wavelength ultraviolet spectra that the supernova's signal was located between the two stellar signals. The researchers concluded that Sk -69°202 had in fact disappeared and was most likely the progenitor star.

The flood of data will continue, as will the analysis of data already received. And continued monitoring is needed to learn where 1987A fits into the overall picture. Will the supernova continue to brighten? Is a pulsar lurking inside, waiting for the obscuring debris to clear before making its presence known? Will x-ray and gamma-ray observations reveal the telltale signature of nickel in the supernova's spectrum? Future observations hold the answers.

## Soviets Build Combined Optical, Radio Telescope

The Soviet Union has completed what is believed to be the world's first combined radio and optical telescope. The radio segment of this new instrument is also said to be "the most precise of all large [radio] antennae in the world," capable of operating "with short radio waves about one millimeter long." The telescope is located 5,900 feet above sea level near the Armenian city of Yerevan at the All-Union Scientific Research Insti-

tute of Radiophysical Measurements.

An article by B. Musayelyan in the Soviet publication *Kommunist* describes the new telescope, called the RT-32/54, as having a fixed radio antenna to reduce the distortion caused by steering an entire reflector. The main reflector is 54 meters in diameter and is said to be within one-tenth of a millimeter of a perfect half-sphere.

The telescope was constructed by scooping out 50,000 cubic meters of rock and placing "more than 12,000 cubic meters of reinforced concrete in a spherical concrete bed for an antenna the height of a ten-story building." This pit was then lined with 3,800 high-quality "Duralumin" panels, each of which is apparently individually aligned.

A 5-meter, 15-ton secondary reflector is supported on a tripod at the focus of the main antenna. To point the telescope, the secondary reflector pivots on hinges. "It was decided to place on the other side of the hinge, as a counterweight, [another] reflector for an optical telescope 2.6 meters in diameter." When this large optical instrument is pointed in the same direction as the radio antenna, the whole telescope is able to observe the same astronomical source in both optical and radio wavelengths.

The first scientific observations with the new telescope detected "a powerful burst of radio emission" from the star Eta Gemini. This was said to be the first detection of a radio burst from a red giant star. Donald F. Robertson.

## International Space University Planned

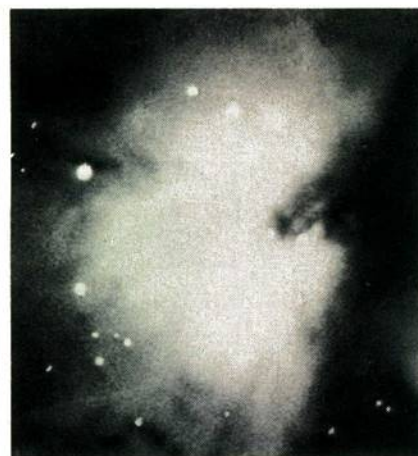
The first steps toward establishing a university dedicated to space-related education and research were taken this April during the Spacefair '87 conference at the Massachusetts Institute of Technology. Plans were made for the first ten-week summer session of the International Space University (ISU), to be held in June 1988 at M.I.T.

Spacefair, attended by three thousand students and over one hundred speakers, included delegations from NASA and the European Space Agency, as well as high-level space officials from Canada, China, the Soviet Union, Japan, and India.

According to ISU officials, the university will begin with summer sessions hosted each year by a different university. By 1992 this format is expected to expand to a full-year program. Initially only graduate programs will be offered; by 1992 undergraduate programs may also be offered.

The goal is to eventually establish academic facilities in orbit, perhaps early in the twenty-first century.

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atmosphere," said science writer Arthur C. Clarke in a videotaped address to the Spacefair conference. "For me, however, there is no better time than now to establish what would become the first permanent human institution on the beachhead of space."

A maximum of one hundred students will be enrolled in the 1988 summer session at M.I.T., which will be conducted at two levels. At the first level a group of students will design a project for space research, such as a space station or a space vehicle; at the second level will be different classroom seminars addressing issues such as space engineering, satellite applications, space medicine, microgravity studies, arts and architecture in space, space law and policy, and entrepreneurship and business in space.

According to Peter H. Diamandis, an M.D./Ph.D. student at M.I.T.'s department of aeronautics and astronautics and chairman of the executive board of ISU, one of the more immediate goals of the space university will be "to foster and to attract new talent into space-related studies and to initiate long-lasting international ties among these future government, academic, and corporate world leaders."

The ISU is sponsored by the Space Generation Foundation, a Washington, D. C.-based organization that will handle the administration of ISU. To get the space university started, the foundation hopes to raise \$1.3 million from private industry, foundations, and participating governments.

## Cloudier Skies in the Forecast?

Have your observing plans been spoiled by clouds lately? Does it seem as if clear skies are becoming increasingly rare? Unfortunately, your impression may be correct. According to a study published in the January 1987 issue of the *Journal of Climate and Applied Meteorology*, skies across the United States have indeed become cloudier during the second half of this century.

The study was conducted by William L. Seaver of the Virginia Polytechnic Institute and James E. Lee of the MITRE Corporation, a nonprofit systems engineering firm. Using National Weather Service data, Seaver and Lee tallied the number of cloudless days recorded in forty-five American cities from 1900 to 1936 and from 1950 to 1986. Fourteen regions of the country, previously identified in a geodetic survey as exhibiting definite cloud patterns during the earlier thirty-six year period, were compared with seventeen regions identified by Seaver and Lee in the most recent period. By comparing the data, Seaver and Lee saw a trend from both periods in which many of the cities showed fewer cloudless days per month during the second half of the century.

St. Louis, for example, averaged 7.2



cloudless days a month between 1900 and 1936 but dropped to 4.7 days between 1950 and 1986; Los Angeles went from 10.0 cloudless days a month to 7.6 days. Only Fort Worth experienced a slight increase in sunshine — from 7.4 to 7.5 days. The most cloudless days still occur in the Nevada-Arizona section of the country, though some of the areas in that section of the country cross over into different cloud-pattern regions.

The hypotheses offered so far to explain this cloudy trend range from the proliferation of jet contrails and air pollution (particulates act as condensation nuclei) to the attraction of excess moisture and clouds by a gradual southward shift of the polar front, a semipermanent front that separates tropical and polar air masses. However, Seaver says, the explanation for the general increase in cloudiness is exceedingly complex because the cloudiness is probably caused by a combination of factors.

## New Submillimeter Telescope Opens Up Unexplored Areas

The largest telescope for observing in the submillimeter range of the spectrum, developed by Great Britain and the Netherlands, is now ready to begin observations of star formation.

With the James Clerk Maxwell Telescope, located at Mauna Kea Observatory in Hawaii, astronomers will be able to study for the first time interstellar gas clouds where stars form, according to the April-June 1987 issue of *Astronomy Now*. Optical study of these gas clouds is hindered by optical radiation, and infrared study is hindered by the cool temperatures of these regions.

The new submillimeter telescope will also help astronomers find the locations of giant molecular clouds in nearby galaxies and contribute to astronomers' understanding of how interstellar molecules are formed and destroyed.

The new telescope was a project of the Rutherford-Appleton Laboratory and Cambridge University with contributions from the Royal Observatory in Edinburgh, Queen Mary College in London, and the University of Kent in Great Britain. Major roles in the development of the telescope were also played by the National Foundation for Radio Astronomy at Dwingeloo, the Netherlands; the University of Utrecht; and the Laboratory for Space Research in Groningen.

## Eiffel Tower Space Art Criticized

To celebrate the centenary of the Eiffel Tower in 1989, the Eiffel Tower Company is planning an illuminated display of space art that would be visible around the world. This space art project, however, will seriously hinder astronomy, states Paul

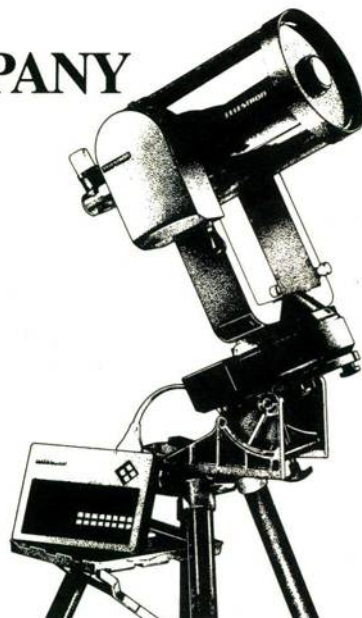
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Murdin, a research astronomer at the Royal Greenwich Observatory in England, in the March 12, 1987, issue of *Nature*.

While Murdin acknowledges that the aims of space artists are aesthetic, he accuses the Eiffel Tower Company of being "egocentric." He hopes these projects and others like them will be canceled.

The directors of the Eiffel Tower Company are deciding between two proposals for the centenary celebration: the Light Ring and Artsat. The Light Ring is a circular structure of tubes that would be inflated to a diameter of twenty-four kilometers after launch when the Sun evaporates water inside the structure. It would appear as bright as one hundred 1st-magnitude stars and cover an area of sky equal to the size of the Moon.

If the Light Ring passes over an optical telescope during an observation, the observation would be ruined. If a sensitive detector is being used, it too would be destroyed by overload from the Light Ring. Murdin said there is a 1 percent chance a telescope will accidentally view the Light Ring on each pass.

The designers of the Light Ring estimate that the satellite will last for three years before it is burnt up in the atmosphere.

Artsat is a curved reflecting sail that would focus the Sun into a cross. Artsat's designer estimates that the satellite could be brighter than the Full Moon, which Murdin says would "make it virtually impossible to carry out observations on faint stars while the satellite was above the horizon."

## Binary Star XY Leonis Actually Four Objects

For many years astronomers have considered the binary star XY Leonis a rather remarkable object because it emits radiation showing intense activity on the two stars' surfaces and in their chromospheres. A contact binary is a double star with members that are in physical contact so that the two stars look like a distorted figure eight.

In March astronomer Samuel Barden at Kitt Peak National Observatory discovered that the XY Leonis system contains four stars, thus shattering the notion that two stars alone emitted all the observed energy.

Barden's discovery raises questions about observations and theory concerning contact binary stars with high levels of activity. According to Barden, "People attributed the observed activity to the contact binary, XY Leo, so that it became a kind of standard to explain certain chromospheric activity in other, similar stars." Now, Barden says, conclusions based on those assumptions are going to have to change. "XY Leo is active, but nothing like we thought — it becomes rather typical instead of remarkable."

Previous observations revealed that sur-

face activity on a star increases as the star's period of rotation decreases but decreases as the rotation period falls below one day. XY Leonis, a system with stars that touch, has a rotation period of about six hours: this was thought to be the cause of its high level of surface activity. "We thought we knew what was going on," said Barden. "It turns out not to be what we thought."

The configuration of the stars in the XY Leonis system is intriguing in itself because it offers evidence that the formation of star systems is even more complex than had been previously thought. The old thinking about solar system formation would have the two binaries rotating in more or less the same plane. But the XY Leonis pairs have very different inclinations: the original binary is inclined 60 degrees to our line of sight, while the new pair is tilted only 30 degrees.

The joined pair contains K-type stars — cool, middle-aged suns — that spin like a twisted dumbbell, completing one rotation every six hours. About as distant from this contact pair as Saturn is from the Sun, the newly discovered binary is a smaller pair of M-type dwarfs more than 2.2 million kilometers apart. They revolve around each other once every eighteen hours and rotate about XY Leo every twenty years.

## Infrared Reflection Nebula Discovered

Astronomers Michael W. Castelaz of NASA's Ames Research Center and John A. Hackwell of the Aerospace Corporation have discovered a reflection nebula surrounding the infrared source R Coronae Australis IRS 5. Announcing their find in the March 1, 1987, issue of *Astrophysical Journal*, the astronomers report that they have mapped the region of R Coronae Australis in infrared light and have found an extended nebulosity that probably consists of an equatorial disk and polar lobes of gas surrounding a faint star in the vicinity.

An infrared nebula emits a great amount of energy in the infrared part of the spectrum because the star that supplies it with light is a strong infrared source. The nebulosity around R Coronae Australis IRS 5 suggests that the star involved is extremely young and may be a protostar that began nuclear fusion reactions recently. Thus, it may afford researchers a good view of how a new member of the Galaxy works.

Astronomers from various institutions will be studying this object closely. So far Castelaz and Hackwell can report that the illuminating star lies above the main sequence and has an effective temperature below 8,000 Kelvins. They also believe that, because of the nebula's exceedingly bluish color, obscuring dust lies between Earth and the star but not between the star and the nebula.



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(graduate credit available, offered during the Astronomical Society of Pacific annual meeting), Pomona College, Claremont, California. Contact: Andrew Fraknoi, Summer Workshop, A.S.P., 1290 24th Avenue, San Francisco, CA 94122. Phone: (415) 661-8660.

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### July 24-26

**Alberta Star Party** (sponsored by the Royal Astronomical Society of Canada, Calgary Center), Chain Lakes Provincial Park, Alberta. Contact: Simon Hum, Quasar Optics, 7220 A, Fairmount Drive S.E., Calgary, Alberta, T2H 0X7. Phone: (403) 255-7633.

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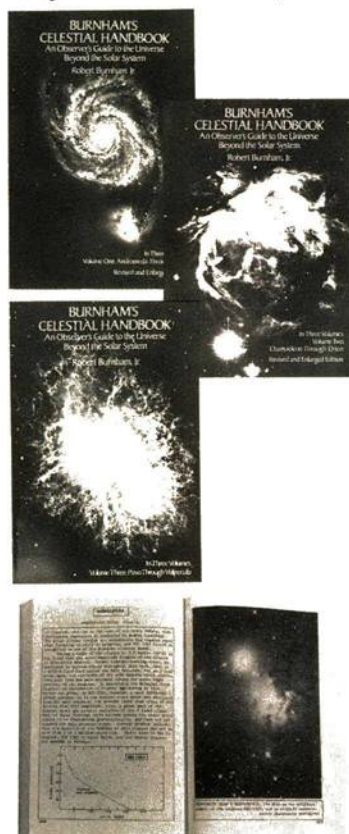
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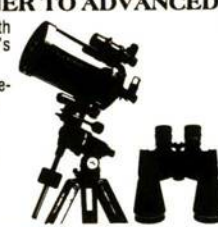
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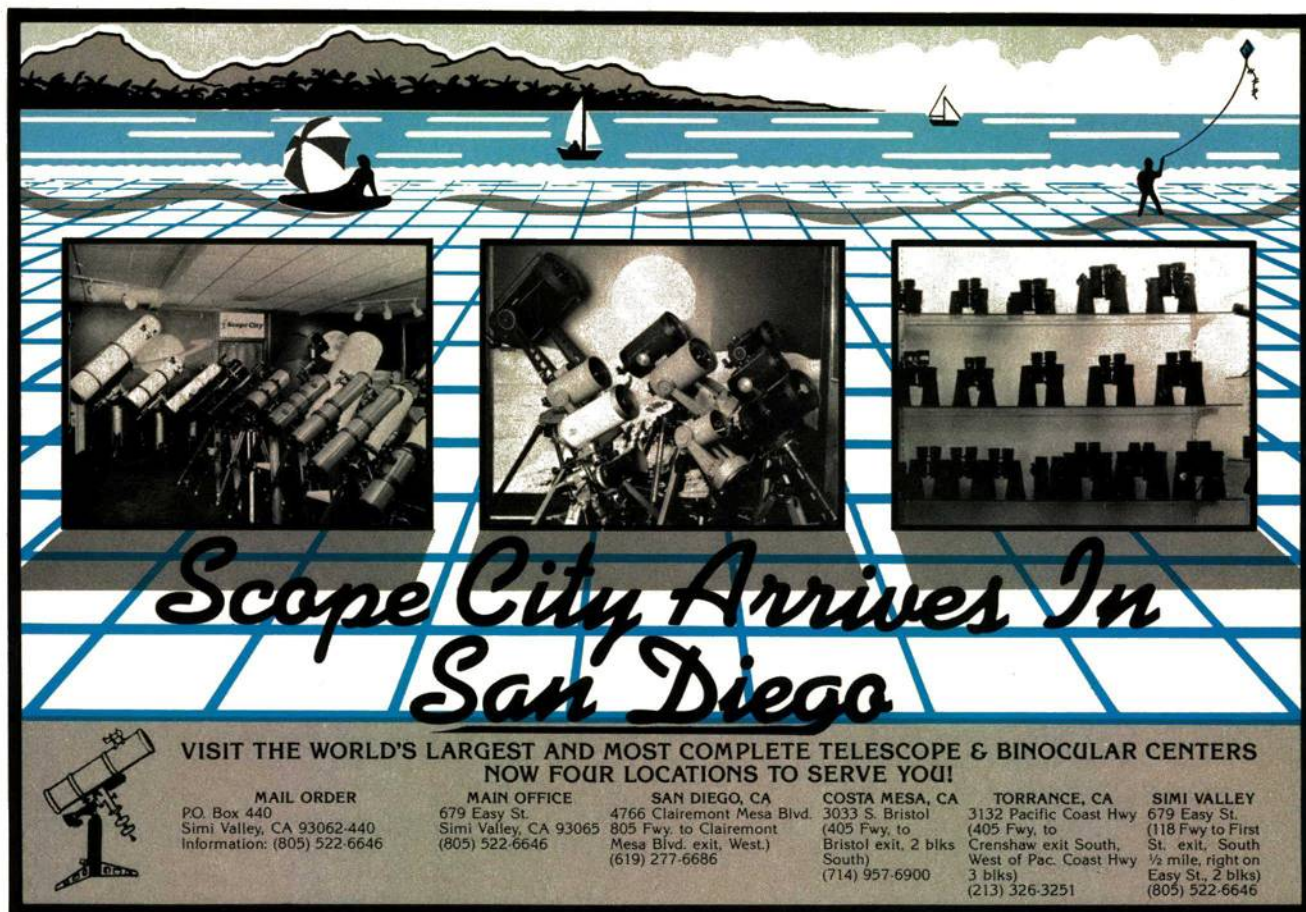
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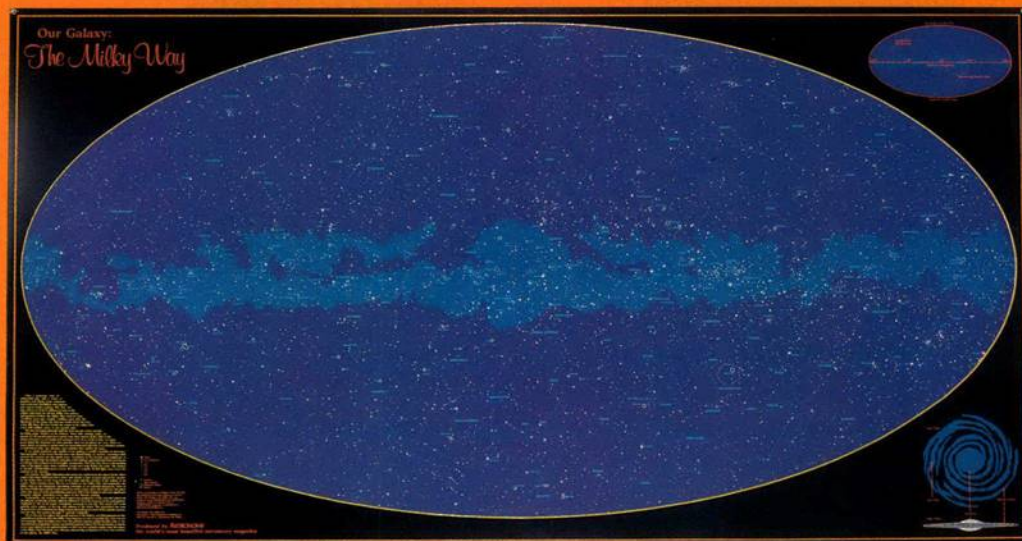
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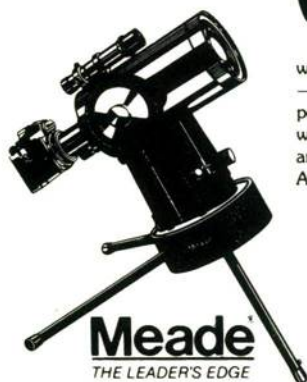
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# The Extreme Ultraviolet

by John K. Davies

## A PROMISING NEW WIN

The space age has revolutionized astronomy. Using telescopes carried above the obscuring blanket of Earth's atmosphere, astronomers can now study the universe right across the electromagnetic spectrum — from gamma rays shooting out of active galaxies to feeble infrared radiation originating in dust barely warmed above absolute zero — and from these observations obtain a more complete view of the universe.

Not all of the different types of electromagnetic radiation falling on our planet have been examined in detail: two important spectral regions are still largely unexplored. One of these regions nestles between the infrared and radio bands and is the objective of the European Space Agency's proposed Far Infrared and Submillimeter Telescope (FIRST). The other, lying between x-rays and the ultraviolet, is the little studied extreme ultraviolet, or EUV. What exactly is the EUV? Why hasn't it been explored already? And what, if anything, can it tell us about the universe?

Defining the extreme ultraviolet is harder than it might appear. Like all such boundaries, the division between the EUV and its neighbors is fairly arbitrary. Often the wavelength range quoted for the EUV depends on who happens to be providing the answer. The situation becomes even more complicated because at one end the EUV merges with low-energy x-rays, where astronomers talk in terms of the energy of individual photons, and at the other end it joins with the ultraviolet, where the type of radiation is usually described by its wavelength.

For our purposes we will define the EUV as extending from 10 to about 90 nanometers (nm). A wavelength of 10 nm corresponds to photons with energies of 125 electron volts and marks the high-energy end of the EUV band. Shorter wavelengths, which correspond to more energetic photons, are called soft x-rays. The reason the long wavelength limit of the EUV is set at 90 nm is bound up with the second question: Why hasn't the EUV been thoroughly probed already?

### Barrier to Discovery

Until recently astronomers believed the interstellar medium was essentially opaque to EUV radiation, so any observations at these wavelengths would be pointless. To understand this reasoning we need to examine the atomic structure of the predominant component of the interstellar medium — hydrogen. Hydrogen is the simplest, lightest, and most common element in the universe. It consists of a positively charged nucleus called a proton, which is orbited by a negatively charged electron. In

interstellar space hydrogen exists in three main forms: molecular hydrogen, consisting of two hydrogen atoms joined together; atomic or neutral hydrogen, consisting of one proton and an orbiting electron; and ionized hydrogen, consisting of a proton from which the orbiting electron has been removed.

Molecular hydrogen usually exists in giant interstellar clouds, where low temperatures and the presence of dust allow atoms to join together into molecules. Ionized hydrogen tends to be found in star-forming regions and in interstellar shock waves where there is plenty of energy to remove the electrons. The atomic hydrogen is spread fairly evenly everywhere else and poses the major problem for EUV astronomers.

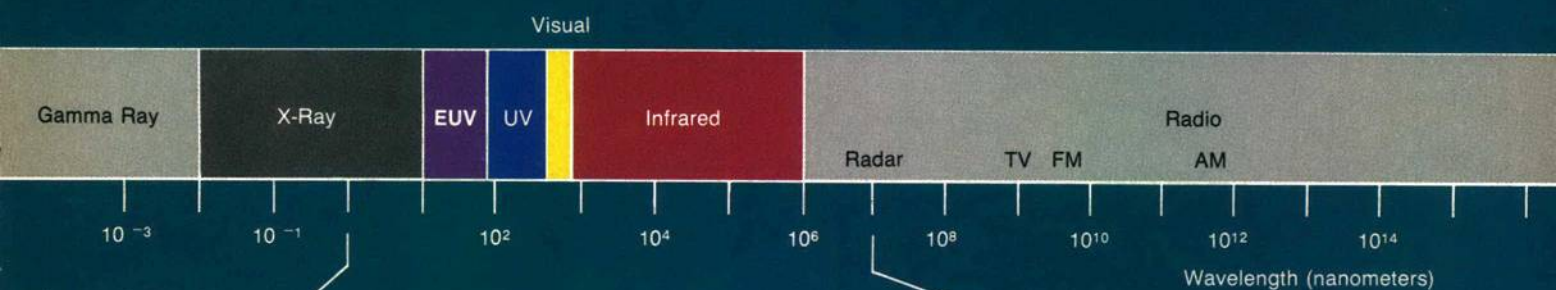
The energy of an EUV photon is just about right to knock the electron straight out of a neutral hydrogen atom or, in other words, to ionize it. Normal ultraviolet radiation does not have enough energy to ionize hydrogen, and x-rays have so much energy they usually pass right through a cloud of hydrogen without hitting a hydrogen atom on the way. But almost every time an EUV photon hits a neutral hydrogen atom, the photon is absorbed, and its energy goes into displacing the electron. The wavelength at which this absorption becomes important starts at about 90 nm (strictly speaking it begins at 91.2 nm, the so-called Lyman limit of hydrogen) and marks the long wavelength limit of the EUV band.

Radio astronomers have measured the hydrogen density in space and concluded that on average there is somewhere between 0.1 and 1 hydrogen atom per cubic centimeter throughout the Milky Way Galaxy. If this hydrogen is evenly spread, then calculating how far a typical EUV photon would travel before being absorbed, and thus how far an EUV space observatory could "see," is easy. Although this distance varies slightly depending on which wavelengths are being studied, the answer turns out to be depressingly close to home — only a few parsecs. This implies that a sensitive EUV satellite would be about as much use as a pair of binoculars in a fogbank and, for many years, space astronomers gave the EUV region a low priority.

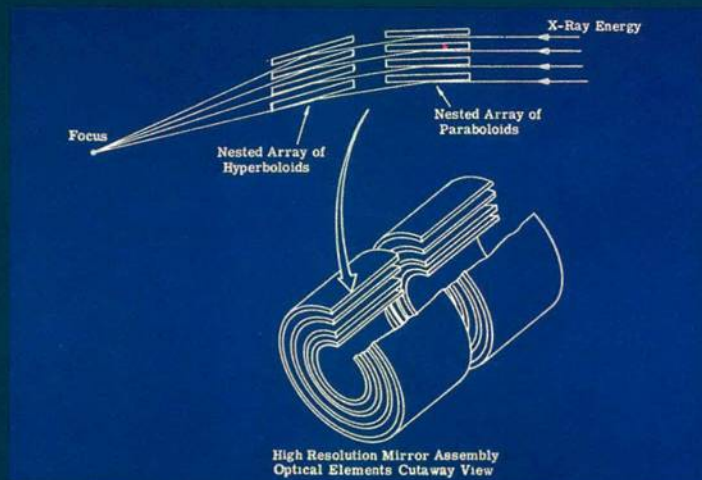
Despite this depressing outlook, a few pioneering EUV astronomy experiments were carried out in the early 1970s. Observations of the Sun were made from unmanned solar observatories and from the Skylab space station, and rocket-launched detectors recorded surprising evidence of EUV radiation from the sky during brief sojourns above Earth's atmosphere. These results encouraged some astronomers to investigate the possi-



# DOWN ON THE UNIVERSE



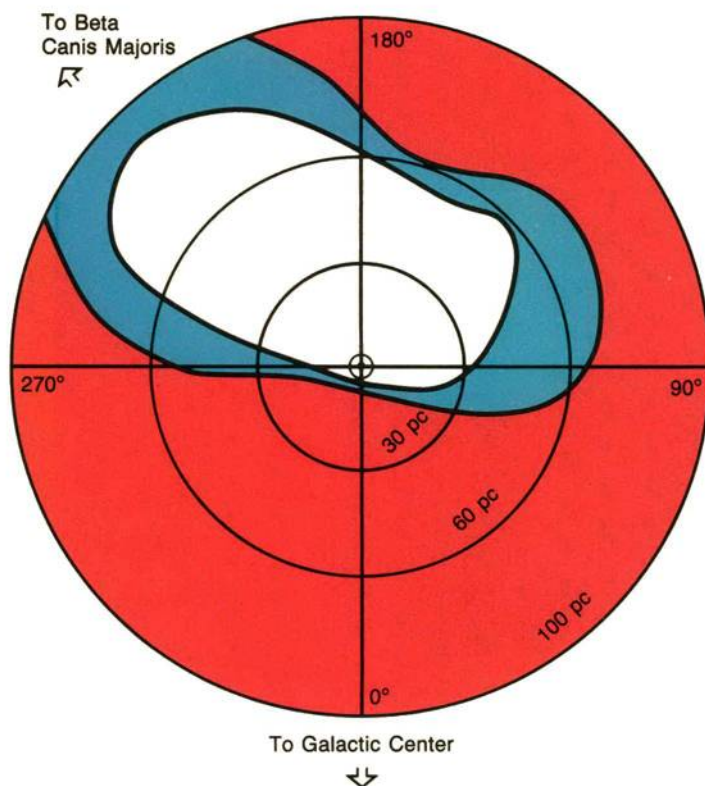
The extreme ultraviolet lies in the high-energy end of the electromagnetic spectrum between ultraviolet radiation and x-rays.



Left: Normal telescopes cannot focus extreme ultraviolet radiation because the high-energy EUV photons would tunnel right into the glass. A technique known as grazing incidence reflection is used instead: photons strike the mirror at a very small angle and skip off, their paths altered slightly to bring the photons to a focus. This diagram shows the grazing incidence telescope of the Einstein X-Ray Observatory. Courtesy Harvard-Smithsonian Center for Astrophysics.



## Visibility in the EUV Depends on Which Way You Look



**Above:** Looking down on the solar neighborhood from above the galactic plane, we can see the distribution of hydrogen in the Sun's vicinity. The Sun is at the center of the diagram and each contour line joins points having an equal column density so, in other words, the density of hydrogen out to each point on the line is equal. A thick wall of hydrogen toward the galactic center blocks our extreme ultraviolet view, but there is a clear area in the direction of Beta Canis Majoris that may extend to 200 parsecs. The area shaded in red is virtually unobservable in the extreme ultraviolet. Diagram based on data compiled by Donald York and Priscilla Frisch.

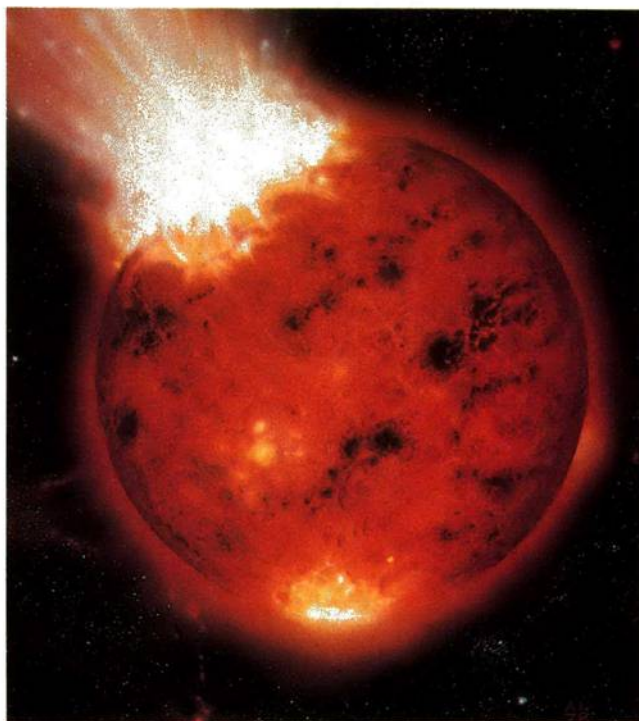
**Top right:** Flares thousands of times more powerful than those on the Sun occur on flare stars. Gases as hot as a million degrees are produced in the process, and this gas emits extreme ultraviolet radiation. Painting by Anne Norcia.

**Opposite page, top left:** The Crab Nebula is the remnant of a supernova explosion. This Einstein Observatory x-ray image shows how that explosion swept away interstellar gas, which produced a hot, low-density cavity emitting high-energy photons. Courtesy Harvard-Smithsonian Center for Astrophysics.

**Opposite page, top right:** The high-temperature corona of the Sun emits a large amount of high-energy radiation. Other stars with hot coronae may also be detected by an extreme ultraviolet space observatory. Solar eclipse photo by Huguette Guertin.

bility of making more detailed EUV observations from orbit. Their hopes were realized when the first orbital EUV telescope flew in the docking module of the Apollo-Soyuz Test Project (ASTP) in 1975.

The pioneering ASTP instrument was built by researchers from the University of California at Berkeley and, because normal lenses and mirrors cannot focus the high-energy photons of EUV radiation, a technique known as grazing incidence reflection was used. Grazing incidence telescopes focus photons that arrive traveling almost parallel to the mirror surface, unlike normal telescopes, which focus light arriving at right angles to the reflect-



ing surface. The mirror of a grazing incidence telescope is somewhat like a bottomless bucket with a highly polished inner surface. When an EUV photon strikes the polished surface, it skips off the mirror at a small angle and heads for the focal plane of the telescope, which lies some distance behind the narrow end of the bucket. This is like skipping a flat stone off water in a pond. If the stone hits at too big an angle, it burrows into the water, but if it strikes almost parallel to the surface, it skips off and heads for the other side along a slightly altered path.

Because only photons that enter around the edges of such a telescope can graze off the reflecting surfaces, a number of slightly smaller mirrors are usually nested one inside another. The ASTP telescope used four mirrors to capture EUV photons and focus them onto an electronic detector. The telescope was also equipped with several thin filters near the focal plane to restrict the range of wavelengths reaching the detector at any one time. By observing the same source through a number of different filters, astronomers can determine a rough spectrum of the object and from the spectrum estimate the object's temperature.

### The First Tantalizing Results

The EUV telescope was used for several hours during the Apollo-Soyuz mission and made two main types of measurements. One of these was a series of observations of specific stars expected to be EUV sources. EUV radiation is emitted by material at temperatures of around 50,000 to 1,000,000 Kelvins — much hotter than a normal star — so the targets were chosen very carefully. They included white dwarf stars and nearby stars believed to have hot coronae — outer atmospheres heated to a temperature of a million degrees. Also studied were members of the class of close binary stars known as cataclysmic variables. These objects emit low energy x-rays as matter flows from one star to the other and is heated in the process.

The other objective was to survey a small region of sky and measure diffuse EUV radiation, a possible lower energy equivalent to the previously discovered diffuse x-ray emission. (See "The Mysterious Cosmic X-Ray Background" by Barry Parker, *Stellar Frontiers*, February 1986.)

The ASTP experiment was highly successful. The telescope detected five stellar sources of EUV radiation as well as diffuse emission from interstellar gas. This success showed that EUV observations of extrasolar objects could be made, which in turn





showed that, at least in the vicinity of the solar system, the density of neutral hydrogen cannot be as high as astronomers had previously thought.

To understand this scarcity of neutral hydrogen, astronomers have observed many nearby stars at optical and ultraviolet wavelengths in an attempt to map the density of hydrogen in the space around the solar system. These observations include studies conducted with the ultraviolet spectrometers aboard the Voyager spacecraft. Designed to study the atmospheres of the giant planets at wavelengths between 50 and 170 nm, the Voyager instruments have been used between encounters to observe the EUV radiation emitted by a sample of nearby white dwarf stars.

Although many of the details remain uncertain, the observations indicate that the amount of neutral hydrogen in the solar neighborhood is well below the galactic average. Apparently the Sun is located near the edge of a diffuse cloud of hydrogen, and the bulk of the cloud lies toward the galactic center. Looking in this direction, EUV telescopes see what appears to be a "wall" of hydrogen that restricts the view to a few parsecs. In most other directions the hydrogen density is lower, so EUV astronomers can expect to see about 75 parsecs before the interstellar gas dims EUV sources below the limit of detection. The best news is that in two particular directions, toward the north galactic pole and along the galactic plane in the direction of the 2nd-magnitude star Beta Canis Majoris, the hydrogen density is very low, which should make EUV observations out to at least 150 parsecs possible.

The reason the local interstellar medium is so low in neutral hydrogen is unclear. One possibility is that the expanding shock wave produced by the explosion of a nearby supernova some 100,000 years ago swept much of the hydrogen away from the Sun. Another possibility is that the gas between the stars is naturally clumpy, and by good fortune the solar system lies close to the edge of one of these clumps. Detailed observations of the diffuse EUV emission may help resolve the nature of the local interstellar medium and is one reason astronomers want to open the EUV window with an orbiting observatory as soon as possible. Astronomers are eagerly awaiting such a mission now that they know neutral hydrogen is not a complete barrier to EUV observations and that many EUV sources are likely to be visible.

#### **White Dwarfs Stand Tall**

What types of objects do astronomers expect to see in the

EUV, and what can astronomers hope to learn about them? To get an idea, let's look at the sources detected by the ASTP, Voyager, and rocket observations. These are listed in the table on page 87. There aren't very many because of the inherent difficulties in observing at these wavelengths and because only about 5 percent of the sky has been surveyed in the EUV so far. The table also shows that more than half the objects — four out of seven — are hot white dwarfs. It may sound a little strange to talk about a "hot" white dwarf because all white dwarfs are hot, but in this case I mean a special class of dwarf star so hot its stars are actually bluish in color.

EUV observations of hot white dwarfs are important because these objects represent a late stage in the evolution of stars like the Sun. When solar-type stars exhaust their supply of hydrogen fuel, they expand into red giants and eventually puff off much of their outer atmosphere, forming a planetary nebula. (See "Breezes, Bangs, and Blowouts: Stellar Evolution through Mass Loss, Part 1" by David Darling, *Stellar Frontiers*, September 1985.) The central stars of planetary nebulae are hot and compact and, as they cool, probably evolve into white dwarfs. The trouble is that astronomers didn't know any stars that lay on the suspected evolutionary path between planetary nebulae and normal white dwarfs until recently. The discovery of hot white dwarfs through their EUV emissions may provide important clues about this stage of stellar evolution.

The brightest EUV star is a 12.9-magnitude hot white dwarf in Coma Berenices called HZ 43. Observed during the ASTP mission, HZ 43 is a true EUV star: it radiates most of its energy between 20 and 60 nm and has a surface temperature of around 60,000 Kelvins. Although HZ 43 is probably about the size of Earth, it weighs about as much as the Sun does and altogether radiates about seven times as much energy as our star.

Figure 24, a 12th-magnitude white dwarf in Cetus, is another strong EUV source observed by the ASTP telescope. Figure 24 has unusual spectral properties and, like HZ 43, appears to have a dwarf red M-star as a companion. The Voyager spacecraft detected two white dwarfs — GD 153 and G 121 B2B — glowing in the EUV. Both are around 12th magnitude and have temperatures of around 50,000 Kelvins.

Astrophysicists are anxious to make more detailed EUV observations of this type of star to determine the stars' chemical composition, which is very important to theories of stellar evo-





White dwarfs are the most common objects detected by the extreme ultraviolet surveys conducted to date. These hot stars are often the central stars of planetary nebulae and are distinguishable by their distinct, bluish color, as in this image of NGC-6781. California Institute of Technology photo.



## **Known Sources of EUV Radiation outside the Solar System**

| <b>Name</b>             | <b>Visual Magnitude</b> | <b>R.A. (2000)</b> | <b>Dec.</b>    | <b>Distance pc</b> | <b>Type</b>                 |
|-------------------------|-------------------------|--------------------|----------------|--------------------|-----------------------------|
| <b>Feige 24</b>         | <b>12.2</b>             | <b>02h35m</b>      | <b>+03°44'</b> | <b>90</b>          | <b>White Dwarf</b>          |
| <b>VW Hydri</b>         | <b>8-14</b>             | <b>04h09m</b>      | <b>-71°18'</b> | <b>190</b>         | <b>Cataclysmic Variable</b> |
| <b>G 191 B2B</b>        | <b>11.7</b>             | <b>05h05m</b>      | <b>+52°50'</b> | <b>48</b>          | <b>White Dwarf</b>          |
| <b>GD 153</b>           | <b>13.4</b>             | <b>12h56m</b>      | <b>+22°02'</b> | <b>40</b>          | <b>White Dwarf</b>          |
| <b>HZ 43</b>            | <b>12.7</b>             | <b>13h16m</b>      | <b>+29°02'</b> | <b>65</b>          | <b>White Dwarf</b>          |
| <b>Proxima Centauri</b> | <b>11.0</b>             | <b>14h30m</b>      | <b>-62°41'</b> | <b>1.3</b>         | <b>Flare Star</b>           |
| <b>SS Cygni</b>         | <b>8-12</b>             | <b>21h43m</b>      | <b>+43°35'</b> | <b>50</b>          | <b>Cataclysmic Variable</b> |

lution, and to find out how the stars cool to normal white dwarfs. A systematic survey of the sky at EUV wavelengths would determine the distribution of hot white dwarfs in the solar neighborhood.

### **Cataclysmic Variables and Flare Stars**

Cataclysmic variables are also of interest to EUV astronomers. These stars brighten by up to several magnitudes in a semiregular way as material spills off a cool, near main sequence star and falls onto a white dwarf companion. The material does not fall directly onto the white dwarf but initially goes into orbit around the white dwarf, forming a ring called an accretion disk. Material falling onto the white dwarf from the accretion disk is heated enough to emit x-rays and EUV radiation.

Several such systems have already been detected in the EUV or in very soft (low energy) x-rays. SS Cygni was seen from ASTP, U Geminorum from NASA's first High Energy Astrophysical Observatory (HEAO-1), and VW Hydri, which may have been detected earlier during a rocket flight, was confirmed as a very soft x-ray source by the European x-ray satellite EXOSAT. Several hundred cataclysmic variables may be visible in the EUV, and detailed studies of them, especially during their optical outbursts, will provide new insights into what drives these erratic variable stars.

Not all EUV stars are quite as exotic as the white dwarfs and cataclysmic variables, nor are they all quite so hot. Proxima Centauri, for example, a small star with a surface temperature of only a few thousand degrees, is notable only because it's the closest star to the Sun and varies irregularly in the optical. Proxima Centauri is a member of the UV Ceti class of stars, also known as flare stars. These stars brighten by several magnitudes in a few minutes and then fade back to normal in a few hours. The sudden brightenings are probably caused by giant flares thousands of times more energetic than those on the Sun, and the EUV emission arises in the million-degree plasma produced in the process. Flare stars are numerous near the Sun, so an EUV observatory should be able to detect many of them when they are flaring. Coordinated optical and EUV monitoring will help astronomers understand what drives these huge stellar flares.

Astronomers believe that hot plasma also causes the soft x-ray emission seen in RS Canum Venaticorum (RS CVn) stars. These are binary systems containing a solar-type star and a subgiant companion that rotates rapidly and possesses a strong mag-

netic field. This leads to a large amount of surface activity, including star spots, that in turn produces million-degree plasmas in the top levels of the stellar atmosphere. Like the UV Ceti stars, RS CVn systems are quite common in our neighborhood and will be easy targets for an EUV observatory.

No one really knows if looking out of our Galaxy at EUV wavelengths is possible. If there are holes in the fog of neutral hydrogen, then EUV astronomers may see a few external galaxies. Some galaxies are unusually bright when observed in ultraviolet light and in soft x-rays, and there are indications that these galaxies may also emit considerable EUV radiation. Whether or not astronomers will be able to detect this radiation, and from it determine the source of these energetic emissions, remains to be seen.

Finally, measurements of the diffuse EUV emission from the sky can be used to probe the hot gas between stars. A map of this diffuse emission may help to tie down existing theories on how much hot gas exists in interstellar space and how it is distributed. It may also resolve the question of whether or not the Sun sits in a bubble created by the explosion of a supernova.

At least two major EUV space experiments are under construction. A group of British institutes is building an EUV instrument called the Wide Field Camera to fly on the German/United States/United Kingdom ROSAT x-ray satellite. Originally scheduled for a Shuttle launch later this year, ROSAT will likely ride an expendable booster into orbit within the next few years. The Wide Field Camera will map the sky at wavelengths between about 7 and 20 nm for six months while the main ROSAT telescope scans the same regions at soft x-ray energies. Once the surveys are finished, both ROSAT instruments will examine individual objects seen during the survey.

Work is under way in the United States on the Extreme Ultraviolet Explorer, or EUVE, a spacecraft also designed to make an EUV survey of the sky. Both the ROSAT and EUVE missions have been affected by the Challenger tragedy, but both will almost certainly fly eventually. When they do, astronomers will open an exciting new window on the universe and begin exploring one of the few remaining frontiers.

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*John K. Davies is an astronomer and aerospace engineer at the Royal Observatory in Edinburgh, Scotland. His last article for ASTRONOMY was "The Herbig Stars" in the December 1985 issue.*



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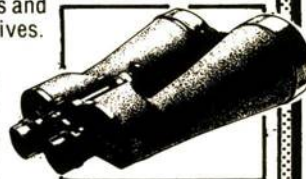
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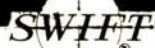


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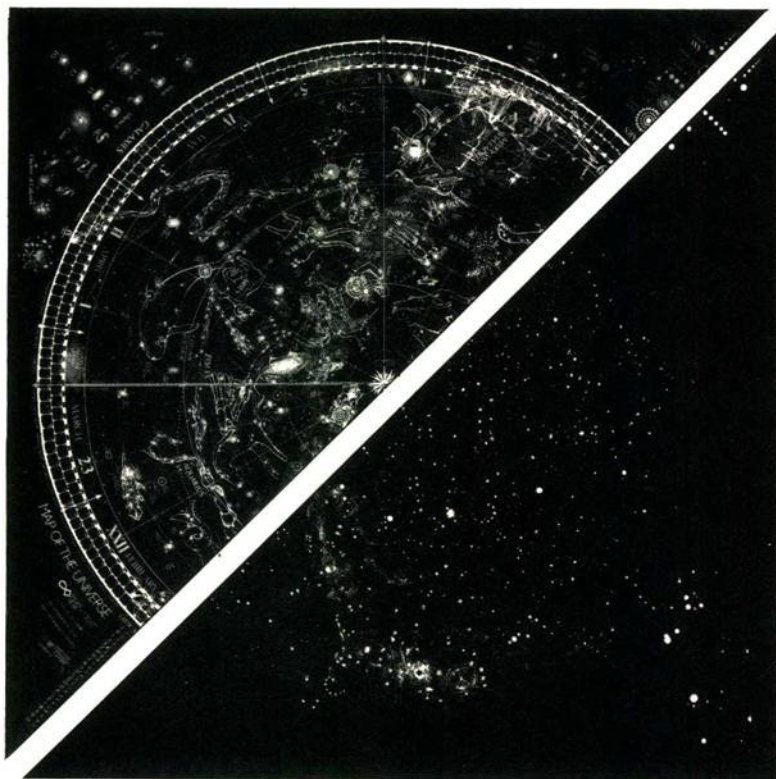
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# A Portable Photographic Platform

by Wallace G. Pursell

## Equipment Atlas

Have you ever wanted to take wide-angle photographs of comets, meteors, or star clusters but couldn't because you don't have a clock drive to track the stars? If so, then perhaps a portable tracking camera platform may be just what you need to overcome this all-too-common astrophotographic impasse.

A camera platform lets you track the stars either by hand or by motor. Because the platform need only support a camera instead of a telescope, there is no need for the trappings of a massive equatorial mount: cradle rings, counterweights, steel pier, etc. In most designs the platform itself is constructed simply of two pieces of straight pine or fir that, when disassembled, fit in a camera bag or under the arm.

The platform is mounted on a pan-head photographic tripod, the pole star is sighted in, and then, after a celestial subject is centered in the camera's view finder, the exposure is begun. During the exposure you turn a drum that adjusts the platform so the platform tracks the target. Exposures of a few seconds to over an hour can be achieved with this simple, homemade platform.

At last April's meeting of the Baton Rouge Astronomical Society, astrophotographers David Taylor and Merrill Hess presented their versions of a simple portable tripod-mounted camera platform. I was so impressed I made one too — with a few modifications. The new design, modestly called the "Taylor-Hess-Pursell Portable Photographic Platform" (THPPPP) is inexpensive, easy to make, and simple to operate.

Here are the materials you will need:

- Two 1" x 4" x 14" good grade white pine or fir boards, *not* warped.
- One 3-1/2" x 3-1/2" butt hinge (Stanley #741 is a good tight hinge).
- One 5/16" x 18 threads per inch (tpi) round-headed carriage bolt, 6" long and fully threaded.
- Two 1/4" x 20 tpi T-nuts (with a 3/4" long throat if you can find them).
- One 5/16" x 18 tpi T-nut.

- Two 5/16" x 18 tpi hex nuts.
- Two 5/16" flat washers.
- One 1/8" x 12" long pipe nipple (or 1/8" IP all-thread steel lamp pipe).
- Two 1" mending plates (optional).
- One cylinder or drum (to be made by you).
- One swivel-head camera mount.

### Constructing the Platform

There are actually two models of the



**The red color of the Orion Nebula and many faint stars "surface" in this short exposure, which shows minimal trailing. The cloudy patch near the top left of this photo is the Rosette Nebula in neighboring Monoceros. Photo by Wallace G. Pursell, who used the camera platform, a 50mm lens at f/1.8, Ektachrome 400 film, and a 3-minute exposure.**

THPPPP. Both allow you to make time exposures of the sky, but the second model includes a couple of refinements that facilitate making long exposures. The parts listed above are sufficient for you to construct the basic model. If you are then so inclined, you can make the advanced model later by securing a few additional items and making a couple of modifications to the original design. But you won't have to buy all new materials.

First we'll discuss how to build the basic

model. Before you begin, be sure the ends of both boards are square. If they are not, carefully trim the uneven ends. A power saw with a saw protractor or, better still, a band saw, radial-arm saw, or miter box will work, but you can also use a hand-saw if you can cut accurately enough. Obtaining a piece of lumber that is longer than you need and custom cutting your boards from that to ensure square ends is a good idea. You can use the scrap lumber later to fashion your drum.

Mark the center lines on both sides of the boards. On the top of the bottom board mark the point on the center line that is 12-3/4" from the axis of the hinge pin. This measurement is critical, so be accurate. Drill a hole at that point and insert the 5/16" T-nut from the top side; tack or screw it into place.

Another critical measurement is the groove for your polar alignment scope, which must be perpendicular to the long dimension of the top board. On the top of the top board, about 1-1/2" to 2" from the hinge end, crosscut a small channel 3/8" wide by 5/16" deep to make a tight fit for the 1/8" pipe nipple to lay in. This cut can be done a number of ways, but I found using a radial-arm saw easiest. However you do it, be sure the cuts are straight and that they are all within the 3/8"-wide groove. Carefully remove the excess splinters with a narrow wood chisel.

About midway along the center lines of both the top and bottom boards drill holes and insert and secure the 1/4" x 20 T-nuts. T-nut flanges should be on the *bottom* side of the top board and on the *top* side of the bottom board; countersink the T-nuts if their necks aren't long enough to extend through the board.

Depending on the height of your camera swivel mount, you may want to add a block of wood as a spacer so the camera can be handled more easily. Place the block of wood on top of the top board and drill through the center; insert the appropriate size bolt.

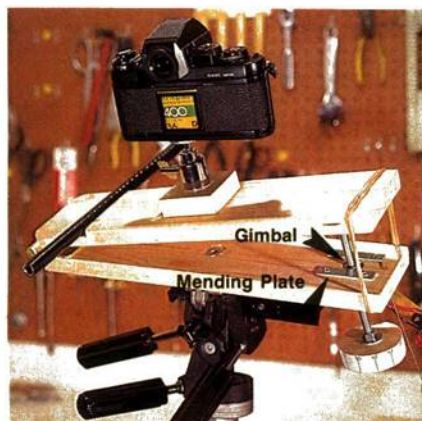
Attach the hinge so the two boards lie



Top: The advanced model of the THPPPP utilizes two refinements (the gimbal and the light) for more accurate and easier-to-make manual time exposures. The gimbal and the mending plates are indicated in the photo at lower left.

Bottom center: Detail of the carriage bolt-drum assembly, upper mending plate (into which the ground point of the carriage bolt inserts), and the light and battery holder assembly.

Bottom right: A gimbal can be made from something as handy as a 5/16" hex nut, drilled and tapped on opposite sides, with machine screws for trunnions.





flat against each other with all their edges lined up and the center lines matching. Be sure to maintain the 12-3/4" distance between the hinge pin and the 5/16" T-nut. This step can be tricky, so take your time.

Adjustments in tracking will be made by turning a rotatable drum attached to the carriage (drive) bolt. The drum should be made from 3/4" or 1" stock lumber with a diameter of 1-7/8" (i.e., a 6" circumference), 2-3/8" diameter (7-1/2" circumference), or 2-7/8" diameter (9" circumference). Although you can fashion this drum yourself with a jigsaw, having someone with a lathe turn this out for you is easier. Cut the lumber slightly oversized and sand it down to the proper circumference. Center-drill a 5/16" hole in the drum for the carriage bolt.

Around the drum's circumference or on a strip of paper to be wrapped and glued around it, mark 5-second time ticks, numbering from *right to left*: 20, 15, 10, 5, M, 55, 50, and so forth. The spacing of the ticks for the different drum diameters is 1/2" for the 1-7/8" drum, 5/8" for the 2-3/8" drum, and 3/4" for the 2-7/8" drum. If you decide to mark the wood directly, be sure to seal it well first.

Now you can put the platform together. First thread the carriage bolt into its T-nut (bottom board) so the underside of the top board rests on the bolt head. Insert the carriage bolt through the drum and secure on the top and bottom with nuts and washers. You will also want to attach a wire at a convenient place on the bottom of the board to serve as a reference mark for the scale on the drum.

Next, press the sight tube in its groove; it should be a snug fit. If it is loose, shim it up with wraps of tape.

#### The More Advanced THPPPP

Your THPPPP is now ready to use. However, as mentioned earlier, there are a couple of refinements you might find worthwhile adding, and they only require a little extra work.

If you want to reduce the tracking errors this drive produces, you can make a small gimbal for the carriage bolt. You won't find this piece in a hardware store so you will have to make it. This can be done a number of ways using light metal or wood. One method is to drill and tap two holes on opposite sides of a 5/16" hex nut (so the axis crosses the center of the hole through which the carriage bolt will pass) and then insert machine screws for trunnions. Make sure the screws do not protrude into the threads of the hex nut. A couple of drops of Super Glue in each screw hole bonds the screws firmly to the nut.

Mount the gimbal in an oval hole cut in the bottom board so the center line (or axis) of its trunnions is exactly at the 12-3/4" distance. Cut little channels in the wood for the trunnions to fit into and hold them in place with two 1" mending plates.



Grind or file a dull point (about 120°) on the carriage bolt; invert it with the drum at the head end of the carriage bolt. On the underside of the top board, at a point exactly opposite the center line of the carriage bolt (12-3/4" from the hinge pin axis and on the center line of the board), make a dimple in the wood to receive the carriage bolt point. Or, to make this more secure, drill and bevel a small hole in a mending plate and then attach it over this spot.

The other modification will make your life a lot easier while you are making exposures. Holding your watch and flashlight, turning the drum to the proper tick, and starting and stopping the photograph can be sort of tricky to do simultaneously in the dark. For less than \$3 (not including batteries) you can make a light to attach beneath the platform that will illuminate your drum.

Go to an electronics supply store, like Radio Shack, and get a double D-cell flashlight battery holder, a flashlight bulb holder with a threaded base, and a package of bulbs 3 volts or less. Mount the battery holder under the bottom board (making sure it won't interfere with the tripod mount). Next attach the bulb holder to a movable arm (using a thin piece of sheet metal) and wire it to the battery holder.

To redden the bulb, you can cover it with layers of red cellophane or vinyl. However, I found it more convenient to double- or triple-dip the bulb (the glass only) in Cryst-L-Craze®, which is a crystallizing glass paint that can be obtained at aquarium shops. The light is turned on and off by screwing the bulb in and out of the socket.

#### How to Use the Platform

Set up your pan-swivel head camera tripod on firm ground and mount your camera platform on the tripod head. The hinge end should point west. Attach the camera swivel on the top board and attach the camera to the swivel head.

Using the sighting tube, sight on Polaris and lock the tripod head into place. You

**The bright starry region around the Hyades and Pleiades in Taurus is excellent for wide-field astrophotography. Photo by Wallace G. Pursell, who used his camera platform, Ektachrome 400 film, and a 3-minute exposure.**

are now in position to track sky objects.

Unscrew the carriage bolt until the two boards are close together. Back up the drum clockwise so "M" is at your reference mark.

Aim your camera at the object you want to photograph and start your exposure. Every 5 seconds very carefully advance the drum to its next mark; do this for the duration of the photograph. If you miss a time tick, be sure to advance the drum to where it would have been if you had not missed the tick. (Normal or wide-angle lenses won't show minor trailing.)

If your platform exhibits too much slippage — either from looseness in the hinge or from the wobbling of the carriage bolt at its point of contact with the top board — add tension by stretching several strong rubber bands from the open end of the top board to the open end of the bottom board. Too many rubber bands are better than too few.

Many astrophotographers are discovering the joys of a simple guided camera platform. Now you can make long exposures of the sky without having to mount a camera piggyback on a telescope driven by a clock drive. Moreover, with only a photo tripod, camera, and compact platform to deal with, you can set up easily and quickly and you don't need an electrical outlet, car battery, or extension cord. The portable camera platform presents an attractive alternative to those looking for a simpler yet accurate way of photographing the stars.

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*Wallace G. Pursell is an avid astrophotographer living in Baton Rouge, Louisiana. His article, "Pursell's Platform: A Southern Alternative to the Poncet," was published in Telescope Making #19, Spring 1983.*





One of the finest barred spirals in the southern sky, NGC-6744 is visible as a 9th-magnitude nebulosity some 10' in diameter. Photo courtesy Cerro Tololo Interamerican Observatory.



## Pavo

Pav

Pavonis

Lying on the fringe of the southern Milky Way not far from the south celestial pole, **Pavo** the Peacock contains a hodgepodge of galactic and extragalactic deep-sky objects. The small constellation contains some galaxies like its neighbors Telescopium and Indus and some galactic objects like the bordering constellation Ara. Unfortunately, only two of Pavo's deep-sky objects appear impressive in small scopes, but the others warrant at least an occasional look.

One of the finest globular clusters in the sky is **NGC-6752**, a magnitude 5.4 collection of yellowish stars some 2° east of Omega ( $\omega$ ) Pavonis. This cluster is easily visible to the naked eye under a dark sky and appears bright in finder scopes. In a 3-inch telescope NGC-6752 appears as a knot of bright nebulosity some 3' across surrounded by a faint haze. A 6-inch resolves the outer portions of this cluster and shows it much larger — spanning nearly 10'. NGC-6752 is a magnificent sight in large telescopes, showing up in a 10-inch scope as a blazing ball of light peppered with faint stars. A 16-inch scope shows countless stars extending nearly 20' across that are so dense toward the center they merge into a yellowish nebulous haze.

NGC-6752 was probably first telescopically observed by J. Dunlop in 1828. One hundred and fifty years later, the expert observer E. J. Hartung characterized NGC-6752 as "a most lovely object; it is a moderately condensed type of globular cluster, the central region about 3' wide." He also noted that many of the cluster's brightest stars are arranged in curved and looped arms and look distinctly reddish. An attractive foreground double star, which contains magnitude 7.7 and 9.3 stars separated by 3'', is visible on the cluster's edge. You might test the sky's

steadiness by checking the lowest magnification that resolves this double star.

The other galactic objects in Pavo are two faint planetary nebulae coincidentally located very close to each other. If you observe with a 12-inch or larger telescope on a very dark night, you may spot **NGC-6630** and **IC 4723** together in the same low-power field of view. Lying 2° south of the 6th-magnitude star Nu ( $\nu$ ) Pavonis, this pair of planetaries is separated by less than 1° in a southeast-northwest orientation.

NGC-6630 and IC 4723 appear almost identical, each glowing dimly at 15th magnitude and measuring 19'' across its long axis. IC 4723 is very nearly circular, but NGC-6630 is slightly flattened — its dimensions are 19'' by 15''. Both of these planetaries are visible as faint, "out-of-focus stars" with high magnification. The surface brightnesses of these nebulae are much too low to show any color: they appear white or pale gray.

About 5° east of these planetaries is the multiple-arm barred spiral galaxy **NGC-6744**. One of the prettiest galaxies in the Southern Hemisphere, NGC-6744 shines at blue magnitude 9.0 and measures 15.5' by 10.2' across. This object is a treat for backyard observers: viewed with a 4-inch scope, NGC-6744 consists of a bright central oval of nebulosity about 2' across surrounded by a very faint glow. Larger telescopes show more impressive views. For example, a 10-inch telescope reveals

a large, oval halo of greenish nebulosity with the bright glow of the galaxy's hub at its center. In addition, this aperture on dark nights plainly shows spiral structure in the galaxy's halo along with several faint foreground stars. Larger scopes show striking detail in the galaxy's arms, including several bright knots of nebulosity and a spiral pattern obvious even to beginning observers. This galaxy should not be passed up.

The fine barred spiral **NGC-6684** lies several degrees east and slightly south of NGC-6744, just 6' south of the 6th-magnitude star Theta ( $\theta$ ) Pavonis. This galaxy is a better-than-average target for small scopes because it shines at magnitude 10.5 and measures 3.7' by 2.7'. NGC-6684 appears as a large oval halo of nebulosity with a bright, almost stellar nucleus. The star Theta Pavonis interferes considerably with observing this galaxy, but observing can be improved on nights of good seeing by using high powers and placing the star slightly outside the field of view.

Three degrees east of NGC-6744 is the elliptical galaxy **NGC-6776**. A 12th-magnitude disk measuring 1.9' by 1.7', NGC-6776 appears like a faint, unresolved globular cluster in most backyard telescopes. Its center is condensed and brighter than the rest of the galaxy, but overall NGC-6776 offers no detail for amateur observers.

Moving 4° north brings us back to the

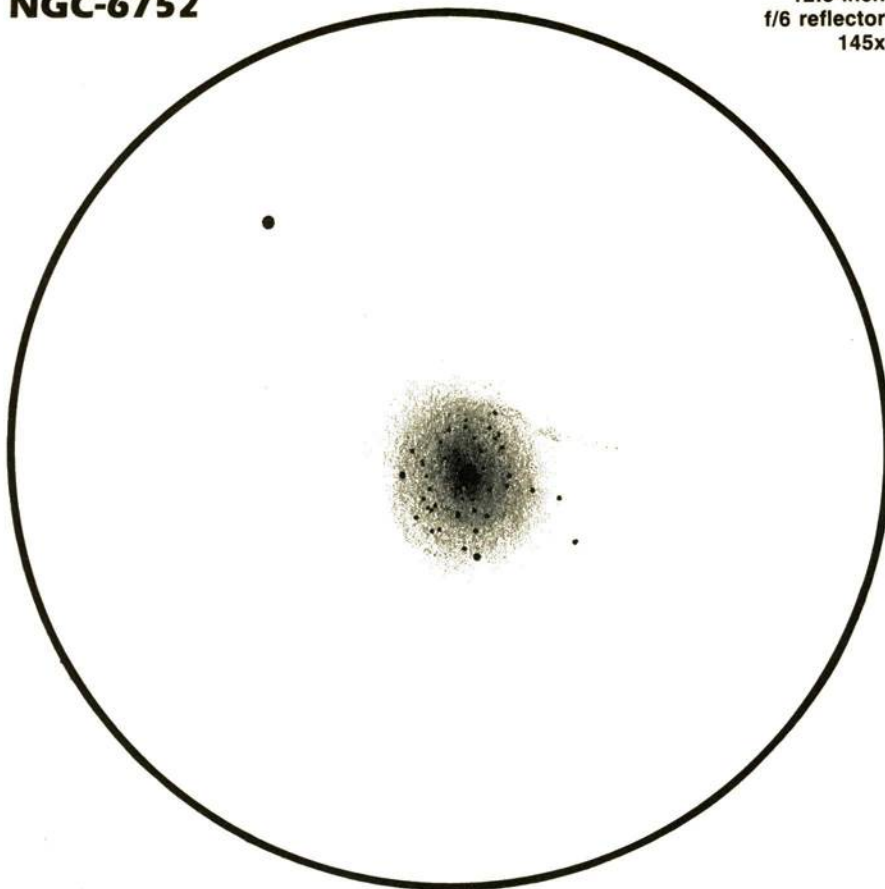


Keith Ward

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.



# NGC-6752



NGC-6752, and you'll spot the spiral galaxy **NGC-6753**. Glowing at blue magnitude 11.9 and measuring 2.5' by 2.2', this little galaxy looks like an elongated smudge of gray light in small telescopes. An 8-inch instrument shows a pale oval nebulosity centered on a much brighter nuclear region.

Lying northwest of globular NGC-6752 region of globular NGC-6752. Look 2° southeast of the cluster and you'll see the faint barred spiral galaxy **NGC-6769**. This object shines at magnitude 11.8 and spans 2.5' by 1.7', which gives it the appearance of a pale, uniformly bright oval of

nebulosity.

Now move your telescope 3.5° north of is the faint barred spiral **NGC-6699**. This galaxy has a blue magnitude of 12.7 and dimensions of 1.9' by 1.8', which make it appear like a faint, round ball of light. NGC-6699's appearance changes little when it is observed with different telescopes: the galaxy remains featureless.

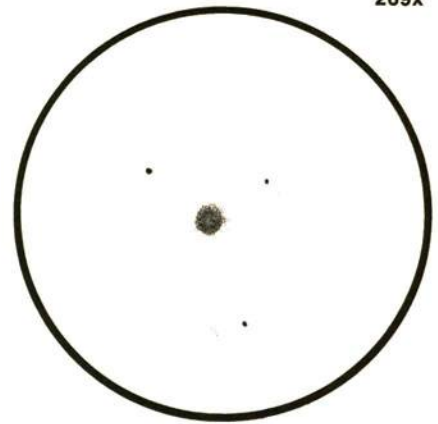
On the other side of NGC-6752, some 4.5° distant, lies the spiral galaxy **NGC-6810**. With a blue-light magnitude of 12.3 and a size of 3.8' by 1.1', NGC-6810 shows no detail.

Four more noteworthy galaxies lie in the

12.5-inch  
f/6 reflector  
145x

# NGC-6753

17.5-inch  
f/4.5 reflector  
269x



Sketches by Jeffrey Corder

southeast corner of the constellation. Only 2° apart and bracketing the 6th-magnitude star Sigma (σ) Pavonis are the galaxies **NGC-6943** and **IC 5052**. On the northwest side NGC-6943 is a 12th-magnitude barred spiral some 4.1' by 2.1' across; it appears as a large, faint haze with a bright center. On the southeastern side IC 5052 is a 12th-magnitude edge-on barred spiral spanning 5.8' by 0.9'. Although it is faint, this galaxy is a fine sight in most backyard scopes because it appears like a thin, silvery needle of light. The central bulge is not much wider than the spiral arms, and the galaxy's center is only slightly brighter than the arms. The field surrounding IC 5052 is very pretty and contains many interesting groups.

Southwest of the NGC-6943/IC 5052 pair is the very faint elliptical galaxy **NGC-6876**. This object glows dimly at magnitude 12.6 and measures 2.4' by 1.8'; it appears as a small, round blob of light without any detail.

Eight degrees northeast of this little galaxy lies **NGC-7020**, a blue magnitude 12.4 lenticular galaxy measuring 4.3' by 2.3'. Viewed with small scopes, this galaxy appears as an oval smear of gray light set amidst a pretty starfield.

| Object   | M# | Type | R.A. (2000) | Dec.    | Mag.              | Size/Sep./Per. | H        |
|----------|----|------|-------------|---------|-------------------|----------------|----------|
| NGC-6630 | ■  |      | 18h 32.5m   | -63°17' | 15.0              | 19"x 15"       |          |
| IC 4723  | ■  |      | 18h 35.8m   | -63°24' | 15.0              | 19"            |          |
| NGC-6684 | §B |      | 18h 49.0m   | -65°11' | 10.5              | 3.7'x 2.7'     | SB0      |
| NGC-6699 | §B |      | 18h 52.1m   | -57°19' | 12.7 <sub>B</sub> | 1.9'x 1.8'     | S(B)b    |
| NGC-6744 | §B |      | 19h 09.8m   | -63°51' | 9.0 <sub>B</sub>  | 15.5'x 10.2'   | S(B)b+   |
| NGC-6752 | ●  |      | 19h 10.9m   | -59°59' | 5.4               | 20.4'          |          |
| NGC-6753 | §  |      | 19h 11.4m   | -57°03' | 11.9 <sub>B</sub> | 2.5'x 2.2'     | Sb       |
| NGC-6769 | §B |      | 19h 18.4m   | -60°31' | 11.8              | 2.5'x 1.7'     | S(B)b pc |
| NGC-6776 | 0  |      | 19h 25.4m   | -63°52' | 12.0              | 1.9'x 1.7'     | E2       |
| NGC-6810 | §  |      | 19h 43.6m   | -58°40' | 12.3 <sub>B</sub> | 3.8'x 1.1'     | Sb-      |
| NGC-6876 | 0  |      | 20h 18.3m   | -70°52' | 12.6              | 2.4'x 1.8'     | E3       |
| NGC-6943 | §B |      | 20h 44.5m   | -68°45' | 12.0 <sub>B</sub> | 4.1'x 2.1'     | S(B)c:   |
| IC 5052  | §B |      | 20h 52.1m   | -69°12' | 12.2 <sub>B</sub> | 5.8'x 0.9'     | SBd:     |
| NGC-7020 | §L |      | 21h 11.4m   | -64°03' | 12.4 <sub>B</sub> | 4.3'x 2.3'     | S0       |

H = Hubble type for galaxies  
 Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.

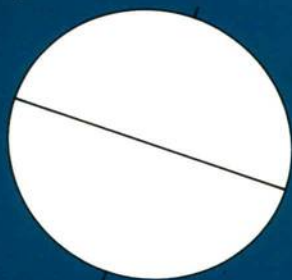
● Globular Cluster  
 ■ Planetary Nebula  
 § Spiral Galaxy  
 §B Barred Spiral Galaxy  
 §L Lenticular Galaxy  
 0 Elliptical Galaxy







Jupiter



Mars



Venus



Mercury



20th 30th

Saturn



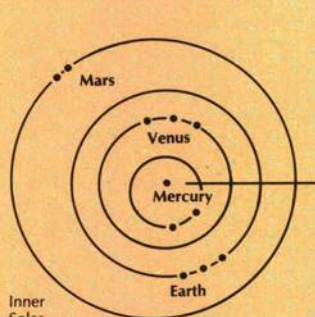
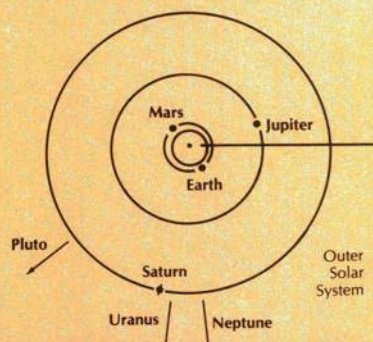
Uranus



Neptune



|           | Date | Mag.  | Angular<br>Size | %<br>Illum. | Distance (AU) |        | Longitude:   |           | R.A. (2000.0) Dec. |           |
|-----------|------|-------|-----------------|-------------|---------------|--------|--------------|-----------|--------------------|-----------|
|           |      |       |                 |             | Earth         | Sun    | Heliocentric | Ecliptic  |                    |           |
| Sun       | 1    | -26.7 | 31.5'           | —           | 1.017         | —      | —            | 98°39.8'  | 6h 38.5m           | 23°09.0'  |
|           | 15   | -26.7 | 31.5'           | —           | 1.017         | —      | —            | 112°00.6' | 7h 35.8m           | 21°37.1'  |
|           | 31   | -26.7 | 31.6'           | —           | 1.015         | —      | —            | 127°17.3' | 8h 39.5m           | 18°24.6'  |
| Mercury ♿ | 1    | 4.5   | 12.0"           | 2%          | 0.562         | 0.462  | 272°40.2'    | 103°41.3' | 6h 58.0m           | 18°43.5'  |
|           | 15   | 2.3   | 10.1"           | 12%         | 0.663         | 0.415  | 315°51.4'    | 97°45.5'  | 6h 32.0m           | 18°51.3'  |
|           | 31   | -0.4  | 6.7"            | 57%         | 1.008         | 0.328  | 26°43.0'     | 109°03.5' | 7h 21.0m           | 21°17.5'  |
| Venus ♀   | 1    | -3.9  | 10.1"           | 97%         | 1.659         | 0.721  | 63°22.8'     | 84°17.5'  | 5h 35.2m           | 22°58.9'  |
|           | 15   | -3.9  | 9.9"            | 98%         | 1.693         | 0.720  | 85°56.3'     | 101°24.9' | 6h 49.7m           | 23°11.3'  |
|           | 31   | -3.9  | 9.7"            | 99%         | 1.718         | 0.718  | 111°50.0'    | 121°04.2' | 8h 13.9m           | 20°43.6'  |
| Mars ♂    | 10   | 1.8   | 3.6"            | 100%        | 2.612         | 1.651  | 131°13.1'    | 122°17.3' | 8h 19.3m           | 20°46.9'  |
|           | 20   | 1.8   | 3.6"            | 100%        | 2.637         | 1.656  | 135°39.2'    | 128°39.9' | 8h 45.6m           | 19°13.1'  |
| Jupiter ♃ | 15   | -2.4  | 39.8"           | 99%         | 4.949         | 4.952  | 15°54.9'     | 27°51.9'  | 1h 45.4m           | 9°30.3'   |
| Saturn ♄  | 15   | 0.2   | 18.0"           | 100%        | 9.196         | 10.031 | 258°57.0'    | 255°40.3' | 16h 58.5m          | -21°08.4' |
| Uranus ♅  | 15   | 5.5   | 3.8"            | 100%        | 18.318        | 19.219 | 265°04.0'    | 263°50.9' | 17h 33.0m          | -23°27.2' |
| Neptune ♆ | 15   | 7.9   | 2.3"            | 100%        | 29.255        | 30.234 | 276°43.0'    | 276°22.6' | 18h 27.5m          | -22°14.5' |
| Pluto ♇   | 15   | 13.7  | 0.1"            | 100%        | 29.413        | 29.684 | 219°07.5'    | 217°24.1' | 14h 41.1m          | 1°35.9'   |

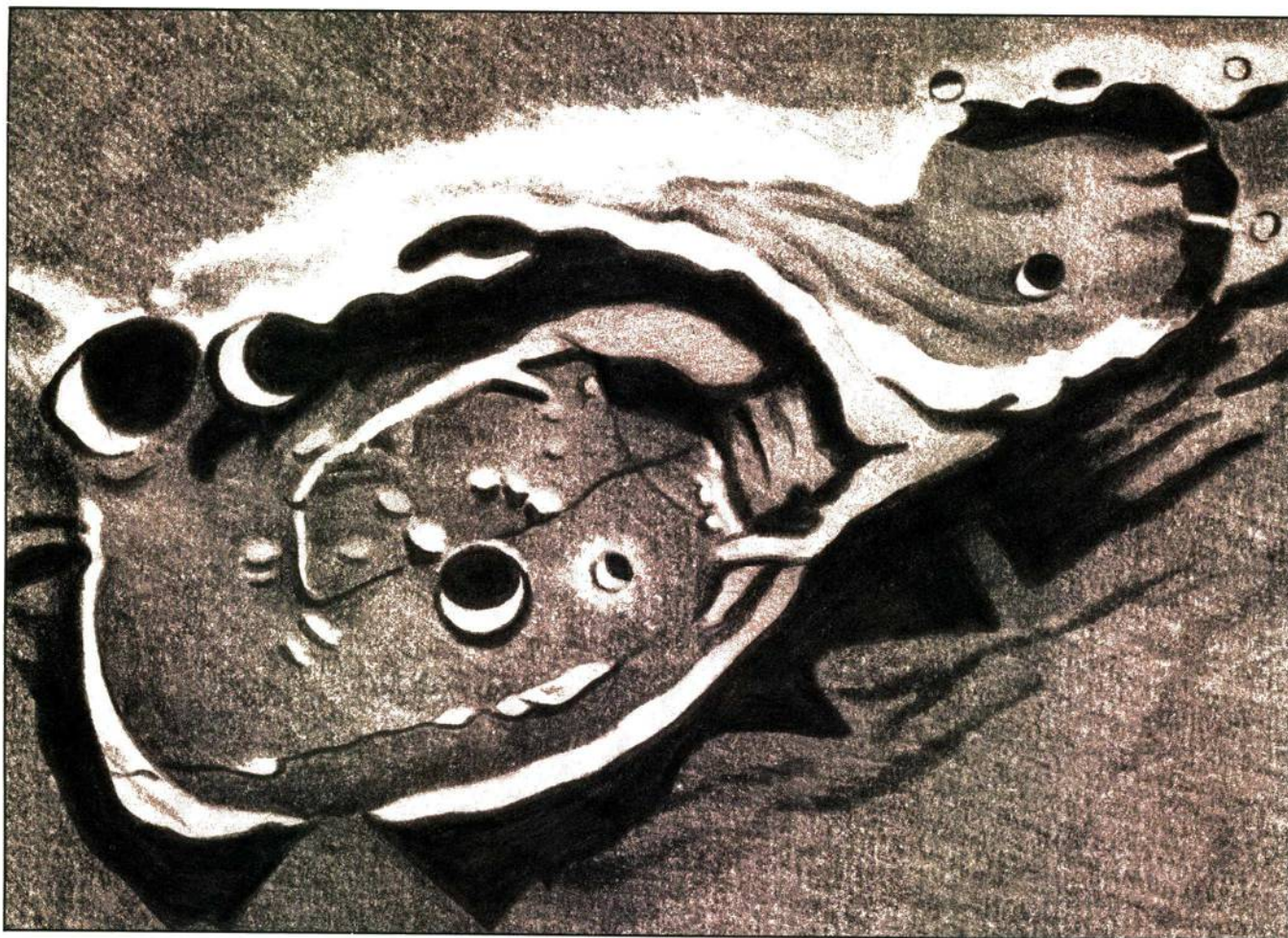
Inner  
Solar  
SystemOuter  
Solar  
System

## Moon Data

First Quarter.....July 4 at 8h34m  
 Full Moon.....July 11 at 3h33m  
 Last Quarter.....July 17 at 20h17m  
 New Moon.....July 25 at 20h37m  
 First Quarter.....Aug. 2 at 19h24m  
 Full Moon.....Aug. 9 at 10h17m  
 Perigee: July 11 at 9h40m.....357,042 km  
 Apogee: July 25 at 7h47m.....406,621 km







The lunar crater Posidonius is a walled plain 62 miles across, adjoining Chacornac and lying on the border of Mare Serenitatis. Visible in this sketch is the central craterlet Posidonius A and mottled detail on the crater's floor. Mark Daniels made this sketch with an 8-inch reflector at 180x.

### Mercury

On July 4, Mercury slips between the Earth and Sun, ending last month's evening apparition and beginning one in the morning sky that lasts until early August. Mercury is visible low in the east-northeastern sky around July 15, shining at magnitude 2.3. The planet's disk measures a diminutive 10" across, and it is only 11 percent illuminated.

The best visibility of Mercury comes near month's end, a few days after the planet's greatest elongation on July 25. In the morning sky on July 29, Mercury reaches a peak elevation of 8° forty-five minutes before sunrise. Your telescope will then show a 7.2", half-lit disk that resembles a small Quarter Moon. Keep observing as twilight brightens and see if the lowering contrast between sky and planet reveals any faint dusky markings on the planet's disk.

### Venus

Venus is visible in the first weeks of July, becoming lost in the Sun's glare by mid-month. The planet shows a fully illumi-

## Satellites of Jupiter

8h00m UT

|    |       |         |    |       |         |
|----|-------|---------|----|-------|---------|
| 1  | JCIEG | • • • • | 16 | EIJGC | • • • • |
| 2  | ECIJG | • • • • | 17 | EJIGC | • • • • |
| 3  | CEJG  | • • • • | 18 | GJCE  | • • • • |
| 4  | CGJIE | • • • • | 19 | GCJE  | • • • • |
| 5  | CGIEJ | • • • • | 20 | CGEJI | • • • • |
| 6  | CGEJI | • • • • | 21 | CIGJE | • • • • |
| 7  | CJJE  | • • • • | 22 | CJIEG | • • • • |
| 8  | CJIEG | • • • • | 23 | CEIJG | • • • • |
| 9  | ECIJG | • • • • | 24 | CEJIG | • • • • |
| 10 | EJICG | • • • • | 25 | CIGJE | • • • • |
| 11 | GJEC  | • • • • | 26 | GCJE  | • • • • |
| 12 | GIJC  | • • • • | 27 | GEJIC | • • • • |
| 13 | GEJIC | • • • • | 28 | GIJC  | • • • • |
| 14 | IJEC  | • • • • | 29 | JIGEC | • • • • |
| 15 | JIEGC | • • • • | 30 | IEJGC | • • • • |
|    |       |         | 31 | EJIGC | • • • • |

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C  
(South is at top, matching the view in a telescope)





On the night of March 5, 1987, the waxing crescent Moon passed within one degree of the Pleiades star cluster in Taurus for observers in North America. Frederick Wasti used a 5.5-inch f/3.6 Schmidt-Newtonian telescope and Kodachrome 64 for this 1-second exposure.

nated disk some 10" across. Venus' conjunction with the Sun comes on August 23, and the planet remains invisible until late September, when it reappears in the evening sky.

#### Mars

Paralleling the actions of Venus, Mars is also sinking out of sight this month. Since it is both smaller and farther away than Venus, Mars is only 3.5" across. In conjunction with the Sun on August 25, Mars will return to view in mid-October, rising in the east just before sunrise.

#### Minor Planets

1 Ceres (magnitude 7.5) is moving westward in southern Ophiuchus, about 1h of right ascension due east of Antares; it is about 6° south and 30m of right ascension east of Saturn. Its positions:

1st: 17h 44m 27s, -26° 18.5'  
10th: 17h 36m 39s, -26° 40.9'  
20th: 17h 29m 47s, -27° 01.2'  
30th: 17h 25m 18s, -27° 17.8'

Ceres sets around 3 a.m. local daylight time on the 15th.

2 Pallas (9.5) is moving south in Serpens Caput. Its positions:

1st: 15h 32m 33s, 24° 32.9'  
10th: 15h 31m 08s, 23° 19.2'

20th: 15h 31m 36s, 21° 45.2'

30th: 15h 34m 06s, 20° 03.1'

Pallas sets around 4:30 a.m. local daylight time on the 15th.

3 Juno (9.1) is nearly stationary in north-central Aquarius. Its positions:

1st: 22h 20m 12s, 0° 03.9'  
10th: 22h 20m 48s, 0° 05.3'  
20th: 22h 19m 17s, -0° 12.4'  
30th: 22h 15m 28s, -0° 52.9'

Juno rises around 10:30 p.m. local daylight time on the 15th.

6 Hebe (9.3) is moving southwestward in a relatively star-rich region near the common border of Aquila and Sagittarius. Its positions:

1st: 19h 54m 44s, -7° 59.6'  
10th: 19h 44m 38s, -9° 06.8'  
20th: 19h 35m 23s, -10° 33.8'  
30th: 19h 26m 11s, -12° 14.4'

At opposition on July 15, Hebe is visible the entire night.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see.

Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

#### Jupiter

A commandingly bright object in Pisces, Jupiter is well-placed for telescope viewing in the morning sky. As dawn brightens on July 1, Jupiter is 37° high (it climbs to 57° by the 31st) and its equatorial disk measures 39" across. Although Jupiter is at perihelion on July 10, its apparent size grows another 30 percent by mid-October, when Jupiter lies closest to Earth.

Because spotting Jovian details becomes easier with practice, try to observe it every clear morning. (Many experienced observers view through photo filters tinted pink, yellow, or light blue.) Continuity in your viewing not only reveals more features but also gives you a pleasing sense of familiarity with the giant planet. There's no thrill quite like that of seeing changes in the cloud belts — Jovian storms each larger than the Earth.

#### Saturn

Located in Ophiuchus where the ecliptic dips nearly to its southernmost limit, Saturn lacks Jupiter's elevation. Nevertheless, viewing Saturn is easier in one sense because Saturn traverses the sky during the evening hours. Saturn's equatorial disk measures 18" and the rings span 41". The planet's northern hemisphere is currently tipped about 26° toward the Sun and Earth, so the broad band of the rings are hiding much of the planet's southern hemisphere, except for low-latitude regions near the equator.

Saturn's disk shows less detail than that of Jupiter; colored filters therefore play a useful role here too. Look carefully for irregularities at the edges of the belts. Don't let a casual glance convince you that the edges are perfectly straight when a closer look may reveal a border that meanders. As with Jupiter, this beautiful planet amply repays patient, repeated viewing.

#### Uranus

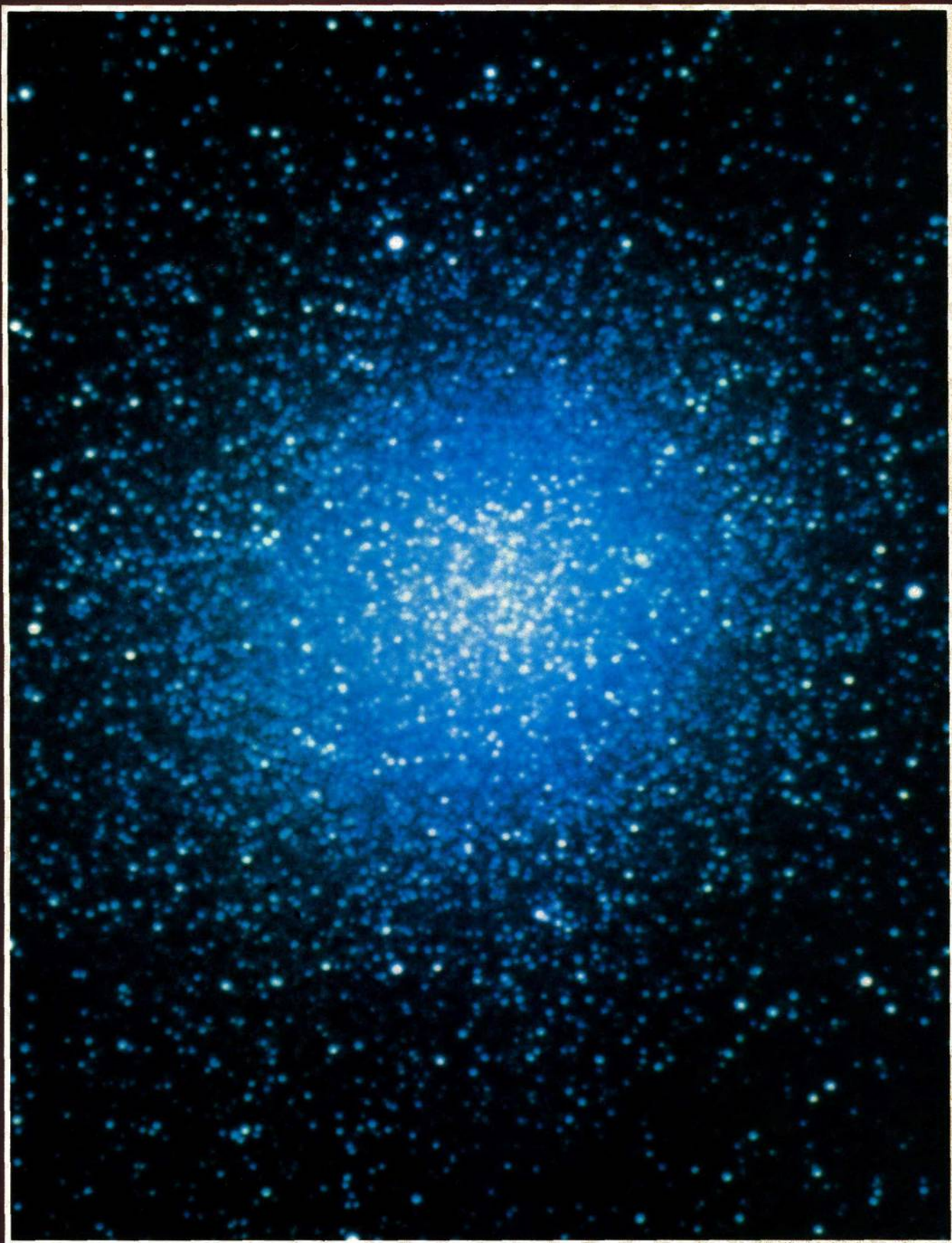
The first time you see Uranus in a telescope, you'll be startled by its bright, greenish-blue color. Its disk spans 3.8" — large enough to be clearly nonstellar even at medium magnifications — and its magnitude of 5.6 places it just within the limit of naked-eye viewing for most people. (Try it once you've located Uranus by telescope or with binoculars.)

Seen nearly pole-on, Uranus' satellites circle the planet's disk in a counterclockwise direction. The brightest is Titania, which circles Uranus at a distance of about 30" every 8.7 days. Because Titania has a magnitude of 14, seeing this moon calls for at least a 10-inch telescope.

#### Neptune

Observationally Neptune is a smaller, dimmer, and grayer version of Uranus. It glows at magnitude 7.9, and its disk is 2.3" across. In a telescope at medium or high magnification it looks obviously nonstellar, but no disk details are visible.





Serge Brunier's photo of Omega Centauri nets him this month's \$100 "Best Astrophoto" award. Brunier, photographing from the Sahara Desert, used a 14-inch SCT at f/6.8, hypersensitized Fujichrome 400 film, and a 60-minute exposure.





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(Shown above)



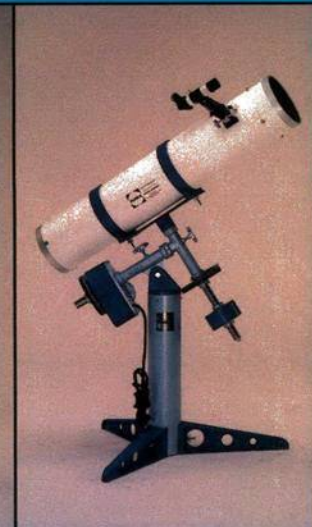
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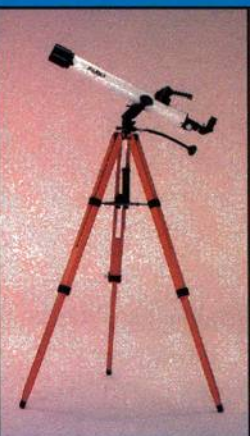
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|---------------------------------|---------|
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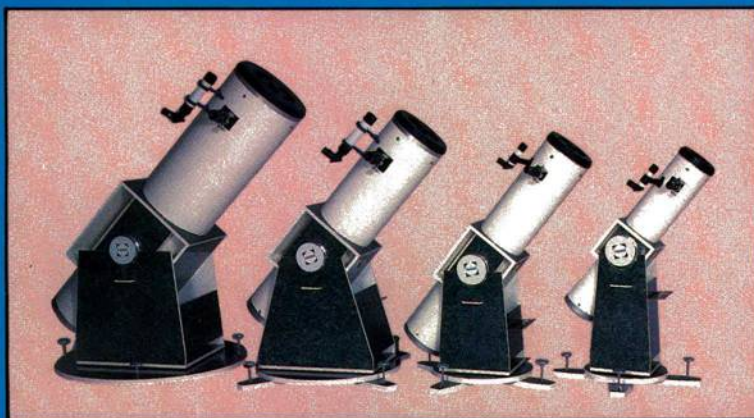
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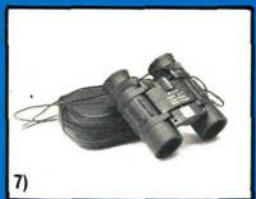
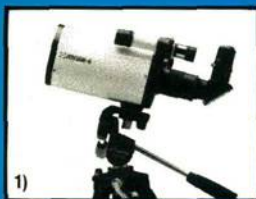
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